"The Electrician" Series.

THE

MANUFACTURE OF CARBONS

FOR

ELECTRIC LIGHTING & OTHER PURPOSES.

BY

FRANCIS JEHL, M.Am.I.E.E.

THE

MANUFACTURE OF CARBONS

FOR

ELECTRIC LIGHTING AND OTHER PURPOSES.

A Practical Handbook,

GIVING A COMPLETE DESCRIPTION OF THE ART OF MAKING CARBONS, ELECTRODES, &c., THE VARIOUS GAS GENERATORS AND FURNACES USED IN CARBONISING; WITH A PLAN FOR A MODEL FACTORY.

BY

FRANCIS JEHL,

MEMBER OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS; FORMERLY
ASSISTANT TO T. A. EDISON, AT MENLO PARK, N.J., U.S.A., AND ENGINEER
TO THE CIE. CONTINENTALE EDISON DE PARIS.

LONDON:
BENN BROTHERS, LIMITED,
"THE ELECTRICIAN" OFFICES, 8, BOUVERIE ST., E.C. 4.

PRINTED BY
FLEETWAY PRESS, LTD.,
1, 2, 3, SALISBURY COURT, FLEET STREET,
LONDON, E.C. 4.

PREFACE.

BOOKS and pamphlets abound upon most branches of electricity and allied subjects, but one notable exception is that of electric-light and electrolytic carbons, such as are extensively used in every civilised country of the world. It is true that "The Electrician" Printing and Publishing Company published, some years ago, a small pamphlet on the subject, but this simply related to the experiments that were made by a gentleman who was not engaged in practical business, but whose work will always find a place in the history of the development of the carbon industry. That so little has been written upon the subject of the manufacture of carbons, and that such a gap has existed for so long a time, is obviously due to the fact that very few have had a chance of thoroughly inspecting carbon works, which are usually as zealously guarded as a fortification. Carbon manufacturers have always been of the opinion that the less said upon the subject the better for them, and it is well known that the art of manufacturing high-grade carbons was always regarded as a sort of secret, of which a few only had the monopoly. It is also evident that as European manufacturers were first in the field, they have gained a large amount of experience which has cost them much time and money, and they are naturally ahead of others in this branch of trade.

It occurred to the author, when he resigned his position with a German carbon firm with which he had been connected for some years, that he could not better utilise his time than in preparing for publication a work upon the modern process of manufacturing electric light carbons, electrodes, &c., which would, no doubt, receive a welcome from many interested in electrical pursuits, especially in England and America, where the manufacture of carbons of a high grade is now receiving attention. The same idea was conveyed to the writer in a letter he unexpectedly received from the Editor of *The Electrician.* As large quantities of carbons are now consumed in almost every country, the question of home production, as already mentioned, is being taken up by capitalists. Many new electro-chemical industries have sprung up, and to these the cost of electrodes, which are needed in large quantities, is a question of vital importance.

It has been the object of the author to give a concise account of the art of making high-grade carbon, and he would here mention that the *secret* of manufacturing high-grade goods lies more in the process of carbonization—that is, *the furnace used*—than in anything else. The author remembers once informing an inquirer that carbons are carbonised in furnaces that use gas as fuel, and the inquirer expressed the opinion that this must be an expensive method. This view is, in fact, expressed by Mr. Pritchard in his pamphlet on carbons, and it occurred to the author that it is not generally known that gas is the best and cheapest kind of fuel to use when a high, steady and well-distributed temperature is desired, and that there must be a general misconception among many, who, as the author later on discovered, thought the gas used was the gas tapped from the mains of a gas works. The author has therefore given a full description and explanation of the gas generator, so necessary in every well-established carbon factory, and has shown its functions in converting every particle of carbon that the fuel contains into carbonic oxide gas, which is the gas mostly used. Then, again, as already mentioned, *the furnace* in which the carbon is carbonised being the most important piece of apparatus necessary for success, the author has given a complete description of the best and most modern systems in use. He has also given ample illustrations of the special machinery used in making carbons, &c., taking as a standard only the designs of the best makers.

As some of the best carbon factories produce their own soot, the author has added a small chapter on this interesting subject, while it may be mentioned that one Austrian carbon factory also makes printing ink with the soot it produces.

The whole object of this work is to show that high-grade carbons can be made and manufactured in every country, and to dispel the idea that the art is confined solely to two or three countries of Europe.

To the works of Ledebur, Stegmann, Köhler and Miller the author has been indebted for valuable data that has helped him to render his description of the gas generators, and soot factory, clearer.

FRANCIS JEHL.

Vienna, 1899.

CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

A Complete Description of how Generator Gases and those Produced by Combustion in the Furnace are Analysed; Explanations why Gas Analysis is Essential to Economy; Dr. Bunte's Burette and its Manipulation; Absorption Fluids.

CHAPTER XI.

CHAPTER XII.

Showing Cost of Manufacturing Electrodes by Electro-Chemical or Smelting Works.

CHAPTER XIII.

Plan showing the Disposition and Arrangement in a Model Factory, drawn to Scale.

CHAPTER XIV.

Theory, and Davy's Hypothesis; The Nature of a Flame; Conditions Necessary for Producing Soot; Data and Tables.

CHAPTER XV.

Early Soot Factories; Gradual Development of the Chamber Condensing System; Soot Factories for Solid and Liquid Fuels; Soot Factories of Germany and of the Bavarian Black Forest; Producing Soot by Means of Lamps, and Notes in Regard to a Feeding System for Supplying Oil to Lamps; Mechanical Apparatus for Producing Lampblack.

APPENDIX.

CHAPTER I.

PHYSICAL PROPERTIES OF CARBON.

Before I proceed with a description of the modern process by which electric light carbons, electrodes and battery plates, &c., are manufactured, I shall consider some of the peculiarities and facts that are known to exist concerning the interesting element (carbon) from which they are made.

Carbon (symbol C), combining weight 11·97, is one of the most important of all the elements, without which no animal or vegetable body could exist. We find it in Nature in the form of the diamond, of graphite, of various varieties of coal, and, in fact, it exists in enormous quantities in combination under a variety of forms. In its purest and rarest form it is found as the diamond, which has a density varying from 3·30 to 3·55. Less pure it occurs in the form of graphite or plumbago and anthracite, the former of which has a density varying from 2·15 to 2·35, while the density of the latter is between 1·4 to 1·6.

Allotropic Forms.—The most remarkable fact concerning carbon is that it exists in three allotropic forms, which forms, as we shall see, have in appearance or physical properties nothing in common. In fact, we see that their densities vary greatly, also that they differ in colour and hardness, while chemically they are all identical. These three allotropic forms are: (1) the diamond, (2) graphite or plumbago, and (3) charcoal. In the form of the diamond carbon is crystallised in forms which belong to the "regular system" of crystallography. Its origin in Nature seems to be unknown. It has been found that when the diamond is burned in oxygen gas it leaves a minute yellowish ash, having a cellular structure. When inserted between the poles of a strong arc it soon swells up, becomes opaque, conducts electricity, the density becoming diminished, and at the same time it is transformed into a mass resembling coke. All these facts, together with the recent experiments made by M. Henri Moissan with the help of the electric furnace, affords, we think, sufficient and conclusive proof that its formation was or is due to crystallisation after fusion, under great pressure, which conditions Nature can and has fulfilled in its past periodical evolutions. Diamond, when polished, has a very brilliant lustre, it possesses the standard coefficient of hardness, and it is a non-conductor of electricity.

All these facts show how totally different it is from form (2). Graphite occurs in Nature either in massive or six-sided crystalline plates of the "rhombohedral system." In commerce it is known either as the amorphous or foliated plumbago. It has a sort of metallic lustre, grey and black, can be easily broken, crumbled, and reduced to powder, and when rubbed on paper it leaves traces, on account of which property it is used in the manufacture of pencils, &c. It is a fair conductor of electricity, and burns or oxidises more readily than the diamond.

The third allotropic modification is charcoal, and includes lampblack made from vegetable or mineral oils, coal, coke, animal charcoal, &c. This form, it may be mentioned, under ordinary conditions, does not crystallise, and has received the name of "amorphous carbon." In general it is an excellent conductor of electricity, oxidises or burns readily, much more so than either of its two other forms already mentioned. It is to this class of carbon that we shall turn our attention, as it is the only kind that is at present suited practically and commercially for the manufacture of carbons used in connection with electricity. It may be mentioned, however, that, when cast iron is melted in contact with a large amount of charcoal, a large proportion of it is taken up, and on cooling it slowly the carbon crystallises into six-sided plates that resemble those of graphite. By means of the arc, or electric furnace, all kinds of carbon undergo this transformation. It is therefore clear that the transformation from one to either of the two other allotropic forms of carbon simply depends upon the functions of heat and pressure.

We shall now take a retrospective glance at what has been done by the early investigators who have worked and experimented in order to attain success in the manufacture of practical electric light carbons.

CHAPTER II.

HISTORICAL NOTES.

Sir H. Davy was no doubt the first to employ carbon electrodes in connection with the arc. His electrodes were simply made out of charcoal—that is, points or rods cut out of carbonised wood—and were neither dense nor homogeneous. It is self-evident that these carbons were very rapidly consumed, a fact which is not surprising when we consider the current and voltage he employed. He used the great battery of the Royal Institution, which consisted of 2,000 pairs of plates, constructed after Wollaston's design, with which he obtained an arc about 10 centimetres (4in.) long. No doubt, if we were to take some of our modern carbons and subject them to an arc of 4in. length they would not last long.

Foucault was one of the first to make use of deposited carbon, or the coke that condenses on the inside of the retorts used in the manufacture of gas. We find, however, that as early as 1846 *Staite* and *Edwards* patented a process of making carbon electrodes by mixing pulverised coke with sugar, which mixture was moulded and subjected to a high pressure and baked until it attained a white heat. It was then again dipped in a concentrated solution of sugar, in order that the sugar might enter the pores and make the whole mass more dense. The electrodes were then subjected to a second baking.

In 1849 *Leonolt* patented carbons which consisted of two parts of retort coke, two parts of wood charcoal, and one part of liquid tar, the whole being worked in a paste, well kneaded, moulded, pressed, covered with sugar or syrup, and then subjected to a high temperature for about 30 hours. Leonolt also tried to purify his carbons after they were baked by immersing them in different acids.

Watson and *Slater*, in 1850, experimented on a similar basis to those above described. *Lacassagne* and *Thiers*, in 1857, tried to purify carbons by immersing them in fused caustic soda or potash, their object being to change the silica which the carbons contained into soluble silicates. The carbons were then steeped in hot water, and afterwards exposed to a current of chlorine gas which passed through a heated porcelain tube in which the carbons were placed. They wanted to convert the various earths that were not acted upon by the soda or potash into volatile chlorides of silicium, calcium, &c. Not long after these experiments, which were of no practical value, *Curmer* conceived the idea to make carbons out of a mixture of lampblack, benzine and turpentine. This mixture, after being kneaded, pressed and baked, left a porous coke, as the benzine and turpentine in a large measure volatilised during the baking. *Curmer* took these porous carbons and saturated them with resin or syrup and then baked them again.

Jacquelain, who was formerly a chemist at the Ecole Central of Paris, made carbons by using the carbides of hydrogen obtained in the distillation of coals, turf, &c.; also from the products obtained by the carbonisation of these materials, which were placed in sealed vessels. He obtained fair results, but would never venture, or was unable, to work out a practical mode of operation.

Gauduin also worked upon carbons which he made out of lampblack. The price of this material, however, was so high at the time that he was obliged to seek some other substance or source. He heated resin, pitch, tars, and oils in closed vessels, and, after decomposition, these left sufficiently pure carbon. The volatile products of the above substances were conducted from the closed vessels by means of worm-tubes and then condensed, and were used again in mixing. *Gauduin* proceeded by pulverising the carbon which was left after decomposition, afterwards mixing it with a certain percentage of lampblack, using as the binding material the carbides of hydrogen which he obtained, as mentioned above, as a secondary product arising from the decomposition of the resins, pitch, oils, &c. He then kneaded the mixture and moulded it by the use of steel moulds, which were then subjected to the pressure of a powerful hydraulic press. These carbons after being baked were considered as superior to those in general commercial use at the time.

Carré, however, seems to have had the greatest success in the production of carbons, which were considered perfect from a commercial and scientific point of view, and we may justly consider him as the founder of the present carbon industry. No doubt the undevóloped state of electric lighting at the time when those early investigators worked upon the problem had a great influence upon their work, and we shall see hereafter that some of them were not far out of the way, and that the modern practice differs from their's only in that the system has since been worked out with more perfect mechanical method. When M. Carré studied the problem, the Gramme machine had just appeared, and a host of inventors were struggling to construct a good arc lamp. There were demands for a good carbon, and one that was practical in every respect, so that on the whole the time was very favourable to the founder of the commercial arc lamp carbon industry. Carré gives an account of his experiments and work in the *Comptes Rendus de l'Académie des Sciences*, February 19, 1877, as follows:—"The superiority of artificial carbons for various experiments, and the possibility of purifying by alkalis, acids, *aqua regia*, &c., the carbonaceous powders that enter into their composition, then led me to seek for some means to produce them economically. By moistening the powders either with syrups of gum, gelatine, &c., or with fixed oils thickened with resins, I succeeded in forming pastes sufficiently plastic and consistent to be forced into cylindrical rods through a draw-plate placed at the bottom of a powerful compression apparatus of about 100 atmospheres. Carbons are now manufactured by this process, and I have at various times presented some of them to the Académie des Sciences and to the Société d'encouragement.

"These carbons have three or four times the tenacity, and are much more rigid than retort coke carbons, and cylinders of 10mm. diameter and 50cm. long may be used without any danger of splintering during a break in the circuit, which often happens with others. They may be as easily obtained of the slenderest diameters (2mm.) as of the largest. Their chemical and physical homogeneity gives great steadiness to the arc; their cylindrical form, combined with the regularity of their composition and structure, cause their cones to continue as perfectly shaped as if they had been turned in a lathe, and therefore there are no occultations of the point of maximum light like those produced by the projecting and comparatively cold corners of the retort coke carbons. They are not liable to the inconvenience of flying into splinters when first lighted, as the others are, in consequence of the great and sudden expansion of the gas contained in their cellular spaces, which are sometimes 1 cubic mm. in capacity. By giving them one and the same uniform density they are consumed by the same amount for an equal section; they are much better conductors, and, without the addition of any substance other than carbon, they are even more luminous in the proportion of 1·25 to 1·00."

Carré's Carbon Mixture.—The mixture which Carré preferred, and patented on January 15, 1876, is as follows:—

Very pure coke, finely pulverised	15 parts.
Calcined lampblack	5 „
Syrup of sugar	7 to 8 „

This whole mixture was well pounded together, kneaded and worked into a sort of hard paste. Afterwards it was pressed through a draw-plate by means of a hydraulic press, and the carbon rods were piled into retorts and baked at a high temperature.

From that period up to the present time improvements have mainly consisted in the perfection of the machines that are used in connection with the raw material, and in the process of baking.

Regarding the priority of the invention of the *cored* carbon there seems to be several claimants. Paul Jablochkoff took out an English patent in the latter part of 1877 wherein reference is made to carbon electrodes having the form of a tube, the hollow part of which was filled with kaolin or glass, &c., while in a French patent (No. 112,024) he states also that the carbon tubes can be filled with a powder, paste or mixture containing volatile matter and carbon. Particulars on this subject will also be found in a work written by Hippolyte Fontaine, published in 1878 or 1879. In the minutes of the *Proceedings* of the Institution of Civil Engineers, Vol. LII., 1877-78, p. 75, we find that during a discussion which took place on January 22, 1878, Mr. F. Higgins made the following statement: "Mention had been made of the cavities, which caused some obscuration of the light, in the carbons of the electric lamps at the South Foreland. That might be remedied by employing carbons formed of a hard *core* of graphite surrounded by softer carbon. The more rapidly burning exterior would leave a point of hard carbon always exposed to the utmost energy of the electric arc." Mr. Weston in America took out a patent also about this time (No. 210,380) for making a carbon having the form of a tube, the hollow part of which was filled with materials or substances that have a quieting effect on the arc. In his patent will be found a long list of such substances.

On July 5, 1879, Louis Siemens took out a German patent (No. 8,253) wherein he claims a solution of a substance in which carbon is suspended, which solution has a beneficial effect on the arc, and is forced under pressure into the hollow carbon. The carbon is then dried. With this patent, later on, Siemens brought suits for infringements against all German carbon manufacturers making a cored carbon, and his patent was upheld, not on the claim of the invention of the core, but on the process of manufacture, for he claimed the process of forcing the coring mixture into the carbon by using pressure. In England, however, Siemens patent was cancelled or rejected on account of the patents of Jablochkoff, Weston, and the particulars published in the book by Hippolyte Fontaine.

The Siemens English patent (No. 2,199, 1879), which received only provisional protection, was as follows:—

"The object of this invention is to produce by means of a carbon connected with the conductor of an electric current a quiet and steady-burning electric light of extreme intensity, in conjunction not only with strong, but also with weak currents, such as it has hitherto been impossible to utilise for illuminating purposes. In order to effect this object a round or prismatic carbon tube is employed, through which is placed a wick, made by preference of glass or any other suitable vitreous substance, or indeed of one or several materials capable of evaporating in the generated high temperature, which, in consequence of their evaporation, cause the flame arc to become a good conductor of electricity, and to be so highly developed as to allow the intensely illuminating points of the two respective pieces of carbon, even when the currents are comparatively weak, to be placed at such a distance from each other that, whilst fully maintaining their illuminative power, the occurence of any jumping or flickering is totally obviated. It is not essential for the wick to be carried exactly through the centre of the carbon, as it may if desired be placed at the side, or several wicks may be placed in various parts of the carbon. For the purpose of electric lighting such carbon may be used in connection either with another of the same description or with an ordinary carbon."

Carré also found that when soda or potash was introduced into the carbons these substances had a tendency to double the arc, render it silent, and, by combining with the silica, which is always present in retort coke, they eliminated it in transparent, glassy globules at about 6mm. or 7mm. from the points. The light was also said to be increased in proportion of 1·25 to 1·00. Lime, magnesia, and strontia increased the light in proportion of 1·30 or 1·50 to 1·00, while giving at the same time different colours according to the substance introduced into the carbon. Boric acid increased the life of the carbons by covering them with a glassy coating, which protected its surface somewhat from lateral combustion, while there were no indications of an increased effect in light. Iron and antimony brought up the increase to 1·60 and 1·70 as regards light.

It was *E. Reynièr* that noticed that a large percentage of the carbon in an arc lamp was consumed by wasteful combustion—that is, by combustion that did not contribute its share of light. He found this combustion going on at the lateral surface of the carbon around the heated points, and that there was a great draught of air continuously washing the lateral surface of the heated points, which thus consumed the carbon. He thought it would be advantageous to thus cover the carbons with a metallic covering. From the experiments which he made at the workshops of Sautter and Lemonnier, Paris, he obtained the following results:—9mm. diameter carbons covered with nickel increased 50 per cent. in life, while

7mm. carbons were lengthened in life up to 62 per cent. Carbons covered with copper also received a lengthened life intermediate between the naked and the nickellised carbons. It may be mentioned that the metals were deposited galvanically. Reynièr also noticed that carbons with metallic covering did not modify the amount of light they gave: there was neither an increase or decrease. This question of increasing the life of the carbons has occupied the minds of men from that time up to the present date. Some inventors cover the carbons first with zinc and then with copper, and thus produce a sort of brass covering which increases the life to a certain extent. The author patented a contrivance some years ago by which the lateral combustion was to a great extent prevented, and the increase in life amounted to 100 per cent. and over. This contrivance consisted of a protecting tube made of steel and lined with refractory clay, which was suspended by means of a wire frame that admitted of adjustment. The frame also carried a small glass cylinder of about 4in. length and 3in. diameter. The bottom part of the frame had a ring made of nickel which had three projecting platinum claws. This whole apparatus is placed on the lower carbon of an arc lamp. This lower carbon (continuous-current lamp) burns, as is well known, always with a sort of a conical point or peak, and on this point the platinum claws rest at about 9mm. or 10mm. from the tip. As the carbon consumes, the ring with the claws and the whole apparatus descend, but keep their relative position with respect to the arc constant. The whole apparatus is adjusted so that the upper carbon projects about 5mm. out of the protecting tube. It will be seen that by this arrangement there can be none, or at least very little, air-washing, and the upper carbon burns away with a flat end instead of a conical one, as in ordinary lamps.

Enclosed Arc Lamps.—The Jandus, Stewart, and General Electric lamps are other devices in order to do away with this lateral combustion. In these lamps the whole arc is enclosed in a glass globe into which very little air can penetrate. The openings at the top and bottom of these globes are just large enough to allow the carbons to pass freely. These openings consist generally of metal rings that are free to move and yet prevent the air entering the globe. The carbons generally used in these kind of lamps are solid for both upper and lower, and generally last from 100 to 150 hours. It is interesting to note the fact that Sir H. Davy enclosed his carbons when experimenting with the arc in a glass globe similar to the arc lamps mentioned above. We find in Ganot's "Physics" the following lines relating to Davy's experiments:—"As charcoal rapidly burns in the air, it was necessary to operate in vacuo, and hence the experiment was for a long time made by fitting the two points in an electric egg." The electric egg is described as: "This consists of an ellipsoidal glass vessel with metal caps at each end." From this we see that the modern enclosed arc lamp can trace its origin back to Davy's time.

All these contrivances, whether the author's apparatus in which the arc was partly enclosed, or as in the Jandus, Stewart and General Electric lamps in which the arc is wholly enclosed, take higher voltage and less current than in the ordinary lamps. The watts remain at about the same value. In fact an enclosed arc under, ordinary conditions, takes about 80 volts and 5 amperes, whereas the lamp, or rather arc, without being enclosed would take 40 volts and 10 amperes.

One of the most important factors in the operation of an enclosed arc lamp depends upon the quality of the carbons employed, as these should be of the highest grade possible; otherwise such a lamp will not work in practice successfully. The high grade carbons that were made by some of the German manufacturers up to 1893 for successfully working open arc lamps on incandescent circuits were not generally suited for the enclosed arc lamp, as they gave off too much dust and soon coated the glass globe enclosing the arc with a thick deposit that lowered the intensity or useful candle-power of the lamps considerably. Then again it was found that, when a lot of carbons were taken at random, their mechanical dimensions varied so (which variation caused no practical difference in the open arc lamps) that when employed in an enclosed arc lamp the life of the carbons varied from 40 to 120 per cent. and even more. In 1894 one or two of the German carbon makers began making a special brand of carbons to suit the electrical and mechanical conditions that exist and are required for the commercial and practical operation of the enclosed arc. These carbons are made from the best of soot, while much more time and care is expended in the process of manufacture than with the high grade carbons that are used for open arcs, as the former should not contain any volatile matter, be of a very fine and homogenous grain, and perfectly straight and of exact diameter throughout their length. Such carbons are consequently more costly to produce, but rank as highest amongst the various grades of carbons on the market.

Pritchard's Experiments.—Mention must also be made of the experiments and work done by O. G. Pritchard, who published in *The Electrician* in 1890 a series of articles upon the manufacture of carbons, which appeared later on in the form of a pamphlet. The process described by Pritchard was the result of eight years' experience, and the author considers that the above-mentioned pamphlet contains much interesting information, of which the following are some extracts. The raw material used mainly by Mr. Pritchard was the foliated graphite which comes from Ceylon, which he tested as follows, in order to determine the amount of pure carbon it contains:

"Take from the bulk and pulverise a small, sample and dry it well at a temperature of 380°F., so as to make sure that all the moisture has been driven off. Take one gramme of this powder and 20 grammes of oxide of lead, also well dried; mix them thoroughly together and pour them into a hard glass test-tube, 5in. or 6in. long, and ½in. diameter. Weigh the tube and its contents carefully, and submit the tube to a white heat under a Fletcher's blow pipe until all gases are driven off and the contents completely fused. Allow the tube to cool, and weigh the residue in the tube. The weight lost is carbonic acid, the oxygen of which has been taken from the lead oxide, while the carbon is all that there was in the graphite. For every 20 parts of loss there must have been 12 parts of carbon." After having obtained the desired quality of graphite, it was "ground to a fine powder in a mortar or pug mill, and then placed in iron crucibles, and mixed with chlorate of potash in the proportions of 18lb. of graphite to 1lb. of the chlorate, and 2lb. of sulphuric acid (sp. gr. 1·8) to 1lb. of graphite. The mixture was then moderately heated until the last fumes of the chlorous gas were evolved, and then allowed to cool, when the excess of the sulphuric acid should be decanted. Upon this sulphated and oxidised mass pour a small quantity of fluoride of sodium, stir well together, and after the chlorous vapours have passed off, the hydrofluoric acid set free by the combination of the sodium with the sulphuric acid will convert any silica present into a gaseous fluoride of silica, which passes away in vapour and leaves the mixture pure. This mass should afterwards be thrown into water and well washed, placed again in crucibles, and submitted to a red heat in a furnace. This will cause the whole mass to swell and disintegrate, forming a light flocculent powder floating on the surface, which must be collected and dried." In order to impart a sharp cutting grain to the mass, Mr. Pritchard took the thin flat plates of gas retort carbon, that are taken from the tops of the retorts, which he ground into a fine powder in the proportions of one part of gas retort carbon to three parts of graphite, well incorporated in the initial stage. He then mixed this material or mixture with sufficient caramel or carbonised sugar, mixed with water, and made a thick, stiff paste, which was placed in an oven and thoroughly carbonised. A material, he says, is thus produced possessing all the desirable qualities. It is perfectly pure, and when ground fine possesses a sharp cutting grain and great hardness, allowing the molecules under pressure to combine to the exclusion of occluded gases, which allows of a perfect homogeneity which could not otherwise be attained. "This material was then crushed and ground into a fine powder that was then passed through a rotary sieve." In explaining the method of the preparation of the saccharine matter employed in combining the material to form the paste, he says, "all materials hitherto experimented upon and used to combine the powdered graphite, such as tar, oils, gums, hydro-carbons, resin, oil, &c., swell the carbons, after being subjected to a drying heat, inducing porosity ; and no available after-process is satisfactory." The material he found to give the best results, which he used to incorporate with the prepared graphite powder, was crystallised lump sugar, although he mentions that he failed when using beet sugar, because when converted into caramel it decidedly loses the adhesive, sticky property belonging to cane sugar. Sugar heated to 400°F.

loses two equivalents of water, becomes brown, cannot be recrystallised, and then is known as caramel. At 410°F. the third equivalent of water is set free, and complete carbonisation commences. In this state the specific gravity is 1·594. The carbon powder was then pugged by adding a sufficient quantity of the liquid caramel to form a paste, which was then allowed to rest and again pugged until it possessed the proper conditions for forming carbons.

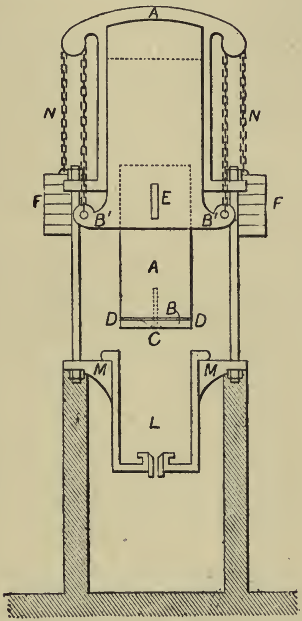


Fig A.—Hydraulic Press used by Pritchard.

The hydraulic press used by Mr. Pritchard for squirting his carbons is shown in Fig. A. The plunger is keyed into the ram at E, so as to be removable. The weights FF consist of iron slabs, 1cwt. each, suspended from the chains NN. Five slabs on either were sufficient to raise the piston. The chains were fastened to the lugs BB, which are part of the casing. The cylinder L, with collar C, drops into the framing MM, fitting tight. The piston is shown at A, while DD is a small groove. With this press Pritchard squirted carbons at about 120 atmospheres pressure, which were cut into the required lengths by a sort of shears operated by hand as the carbon rods issued from the press. The cut carbons were then placed in grooved plates, made of sheet tin, which were stored on racks in the press room. These plates and carbons were then transferred after some time to a drying room, and gradually subjected to a higher temperature until about 200°F. was attained. After the carbons were well dried and showed no tendency to bend by trying them, they were packed in kilns to be carbonised. Fig. B shows the type of kiln used by Pritchard, and of which he says:—"My system is to lay firebricks on the flat, and well grouted with cement; upon which two long sides of the kiln BB, with bricks on edge, well laid in cement, composed of three parts of Stourbridge clay and one part of iron grindings. The sludge arising from the grindstone, well mixed, forms a valuable cement, and will not crack under extreme heat. A crack in the kiln admits air, and disintegrates the carbons. The short ends of the kiln are built with bricks on the flat, AA; the thicker the ends are the better, but 4½in. are sufficient. The kiln must be 2in. longer than the width of two of the plates, and 2in. wider than the length of the plates, which should be 2in. longer than the carbons. This allows for filling in with sieved ashes, which should be kept perfectly dry; any trace of moisture will show itself in the partial disintegration of the carbons. The lines at CC (Fig. B) show the direction in which the carbons are to

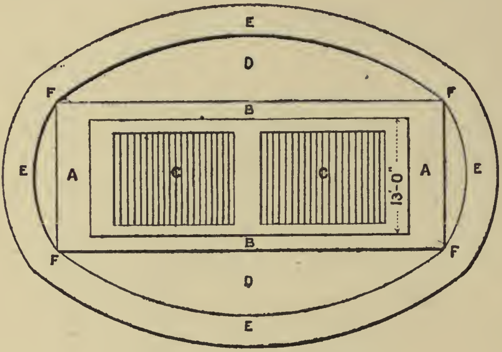


Fig. B.—Kiln (Ground Plan).

be packed. The ends AA are made thick to avoid any lateral heat; the fires being made at DD tend to keep the carbon straight. Any heat in the direction of AA would inevitably twist them. After the kilns are packed and covered over to a depth of 2in. with the ashes, the surface had better be covered with a sheet of tin, and built in with firebricks, well filled in between the joints with the prepared cement, and pointed before using the kilns. After constructing the kiln a fire should be made in and around, so that it may be perfectly dry when used. The trays in which the carbons are fired must be kept solely for that purpose. The furnace consists of a ring of firebricks, built as shown at EEEE (Fig. B), with interstices between them of about 2in., EE (Fig. C). This circular wall should impinge upon the kiln at FF (Fig. B) to keep the heat from the sides AA. The bricks are laid loose without cement, and are built to the height of the kiln.

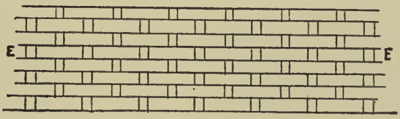


Fig. C.—Brick Wall of Furnace.

The fires must be lighted at DD, gradually adding coke as the fire advances, eventually increasing the height of the walls about a foot higher than the kiln. If the fire is lighted the first thing in the morning it should not be piled over the top until the evening, and this done only by covering with coke and banking over with cinders and clay. Allow this fire to die out, and the carbons will be found, on opening, when cold, sufficiently carbonised for the after-process. The second or final firing has for its object the contraction of the carbon molecules, and therefore an increase in density and conductivity. The first firing, however, must be sufficiently prolonged to effect the carbonisation of the caramel, otherwise when placed in the hot saturating bath the carbons would become partially disintegrated. The second firing should be conducted as follows :—Bank up as before mentioned in the evening; on the following morning rake out the lower holes all round, and keep a strong fire all day all over the kiln. Bank up partially in the evening, and more completely the following morning. Three days after, on opening, the kiln will be found at a white heat. When it is desired to withdraw the carbons, pull down the retaining wall, and clear away the fire and accumulated ashes, and expose the kiln to the air. Do not open before you can bear your hand on the outside. The top bricks may be taken off, and the kiln emptied, if the carbons are not too hot to hold. I should mention that straight carbons will twist if exposed to the air hot from the kiln, but if once allowed to cool no after-firing has the least effect upon them." It may be mentioned that Mr. Pritchard saturated his carbons in a sugar, or rather syrup solution, while one of his methods of coreing is similar to the manner in which carbons are nowadays cored, with the exception that he uses a different coreing mixture and fired his carbons after coreing.

CHAPTER III.

FACTS CONCERNING CARBONS.

Modern electric light carbons—that is, high-grade carbons—are made principally in Germany, and of late years the goods of the German manufacturers have gained a pre-eminence that has taken the shine away from some of the pioneer firms who gained a worthy reputation in the early days, but who have continued the work *per descendum*, and kept their old mill agoing as they did 10 years ago. France and Austria also contribute a small percentage of these carbons to the world, yet it is surprising to see how many German carbons find their way into the Austrian and Hungarian market, while at the same time they are preferred to the home make. It may be mentioned that Charlottenburg, near Berlin, and Nürnberg are the great centres of the high-grade carbon industry. In the United States, however, there are manufactured yearly nearly ten times the total products of all the European factories together, but the carbon is a low-grade one, and is coppered. To talk of a copper-covered carbon nowadays is sufficient to designate its inferior quality. Nevertheless, there are more than 150,000,000 of them made yearly, and all "solids," as in America they use only solids for both uppers and lowers. However, the advantage of the cored carbon is beginning to be recognised, and where good lighting is desired many foreign carbons are employed. There are also carbon manufacturers in the United States who are striving to make a carbon that will compete with the foreign make, but up to the present there seems to be some difficulty which they have not yet overcome; nevertheless, the quality is not to be despised. No doubt the author will be able to show them where the "bug" lies, and that they will soon be able to manufacture a carbon which will be on a par with any on the market.

There has always been an idea prevalent that the European manufacturers have the secret of making high-grade carbons, and it may be mentioned that many of these manufacturers have cherished this bogey. Just before the fall of the Roman Empire it was thought that China had the secret and monopoly alone of making silk, until two monks hid some of the silkworms in their bamboo staffs and brought them West, and established the silk industry in their own country. It is thus the author's object to dispel these illusions, and show that high-grade carbons can be made in every civilised country. There are about $300,000 worth of foreign carbons enter the United States yearly, although there is an *ad valorem* duty of 30 per cent. on them. At the following invoice prices per 1,000 feet carbons are now allowed to enter the United States and pass without re-appraisement* :—

Diameter of carbon in mm.	Cored.	Solid.	Diameter of carbon in mm.	Cored.	Solid.
6	$3.81	$3.04	17	$15.24	$13.71
7	4.57	3.81	18	16.76	15.24
8	5.33	4.57	19	19.05	16.76
9	6.09	5.33	20	20.82	19.05
10	6.85	6.09	21	22.86	20.80
11	7.62	6.85	22	25.40	22.86
12	8.38	7.62	23	27.94	25.40
13	9.14	8.38	24	30.48	27.94
14	9.90	9.14	25	34.29	31.75
15	11.43	10.16	30	48.26	43.18
16	13.20	12.19			

It will be seen that these invoice prices, which allow carbons to pass, are very liberal and just; in fact, they are the terms which only very large buyers of carbons here in Europe receive at present for a second-grade quality, although, no doubt, first-grade carbons enter the United States at these figures. High-grade carbons cost about 10 to 20 per cent. more than the table shows.

---

* Since the above was written, the writer has been informed that the duty on carbons has been raised.

There is also another question agitating the United States Custom Department at present, and that is: Are electric light carbons minerals, or composed of mineral substances? Now those who understand the manufacture of electric light carbons, as made at present, cannot say they are not minerals, as the carbons are made of minerals in the true sense of the word. The object of some of the European manufacturers who affirm the opposite is simply to gain 10 per cent. of the duty, as carbons appraised as non-mineral pay only 20 per cent. *ad valorem* duty. But who would take an oath and say that tar made from coal, gas retort carbon—a product of coal, petroleum coke made from a mineral oil, and lamp-black made from coal-tar, coal-pitch, coal or mineral oils are not minerals? All these mineral substances are used in the manufacture of carbons.

It has often been a surprise to the author, while he was connected with a well-known carbon firm, that the industry—that is, carbon manufacture—should be confined to that parcular geographical position in which it is now situated. There are other positions on this earth as favourably situated, while there are some places possessing far more advantages. There is no reason, for instance, why England should not make high-grade carbons; further, there is no reason why the United States, with its immense petroleum wells and natural gas springs, should not supply the world with all grades of carbons. Russia and other petroleum countries have also an advantage in starting carbon factories and supplying their own market; in fact, the whole carbon business seems to fraternise with the coal-gas manufacturers and petroleum distillers. There is, therefore, no reason for the present state of affairs in this regard; in fact, it would be to the general advantage if the concerns just mentioned would engage in the manufucture of electric light carbons, &c., out of their waste products. With their tars, pitches and residual oils they could make the best of lamp-black for high-grade carbons, while the petroleum coke and gas retort carbon would make carbons of the second grade, electrodes, &c.

CHAPTER IV.

THE MODERN PROCESS OF MANUFACTURING CARBONS, Etc.

The raw material used in the manufacture of modern electric light carbons, electrodes, battery plates and carbon brushes are the following, and the table gives the price per 100 kilogrammes (=220lb.):

	£	s.	d.	$ c.	Fl. Kr.	Francs.
Lampblack, per 100 kilo.	1	6	8	6.40	16 00	32 00
Gas retort carbon	0	8	4	2.00	5 00	10 00
Petroleum coke	0	6	8	1.60	4 00	8 00
Tar	0	6	8	1.60	4 00	8 00
Waterglass	1	13	4	8.00	20 00	40 00

The prices are taken f.o.b. Vienna, and are a little higher than the cost of raw material, the florin being taken as equal to about 1s. 8d. or 40 cents U.S., or 2 francs.

Electric light carbons of the best quality are made from lampblack mixed tar, which is the binding material. Carbons of second quality are made of lampblack, petroleum coke or gas retort carbon and tar, the proportions of which vary according to the maker and quality. Common carbons are made either of petroleum coke or gas retort carbon mixed with tar. Electrodes are composed of the same mixture as the common carbons. The same may be said of battery plates and carbon brushes, with the exception that the latter mixture also contains some plumbago, which imparts a sort of lubricating property to the brush. Formerly carbon brushes were made by Carré from the finest material and were in great demand, but to-day experience has proven that the common American carbon brush is preferred to those made formerly by Carré.

The tar that is taken in the above mixtures amounts to from 25 to 33 per cent. of the total weight. It is obvious that when too much tar is taken the carbon mixture will be too soft and will not require much pressure to force it out of the press. If too little tar is taken it will not be enough to work the mass into the plastic condition which is desirable. A little experience will soon show what proportion to take, as the end to be attained is to get the carbon mixture into a plastic mass, which when compressed into cakes and then forced or squirted out of the press will require from 350 to 400 atmospheres constant hydraulic pressure.

In the prices given in the above table that of the petroleum coke is taken as meaning 100 kilos. of petroleum coke calcinated, as otherwise 100 kilos. when calcinated leave only about 70 kilos., 30 per cent. of which consists of water and volatile matter, which disappears. The following table shows the proportions taken in making the carbon mixtures, and it will be seen that the amount of tar taken is rated at 20 per cent., although in practice it varies from 25 per cent. to 33 per cent. As later on estimates will be given showing the costs of production, the author has taken 20 per cent. in order to have a better margin in calculations.

Carbon Mixtures.

Highest grade mixture consists of...	80 per cent. lampblack and 20 per cent. tar.
Second ,, ,, ,, ...	50 per cent. lampblack, 30 per cent. gas retort carbon or petroleum coke, and 20 per cent. tar.
Third ,, ,, ,, ...	30 per cent. lampblack, 50 per cent. gas retort carbon or petroleum coke, and 20 per cent. tar.
Common American mixture, also for battery plates and electrodes	80 per cent. gas retort carbon or petroleum coke and 20 per cent. tar.
Carbon brushes.........................	65 to 70 per cent. petroleum coke, 10 to 15 per cent. plumbago, and 20 per cent. tar.

We will now proceed to explain the process of manufacture, starting from the store house that contains our raw material, and go through each successive stage until we land our finished material in the shipping department.

Every respectable carbon factory is in communication with its various departments by means of push waggons that run on a narrow gauge rail, with turn-tables at junction points. By these means the material and carbons can be transported from one department to another with facility and saving of time. We will now push one of our waggons into the storehouse where the raw material is kept, and bring in a load to be worked by the crushing mill.

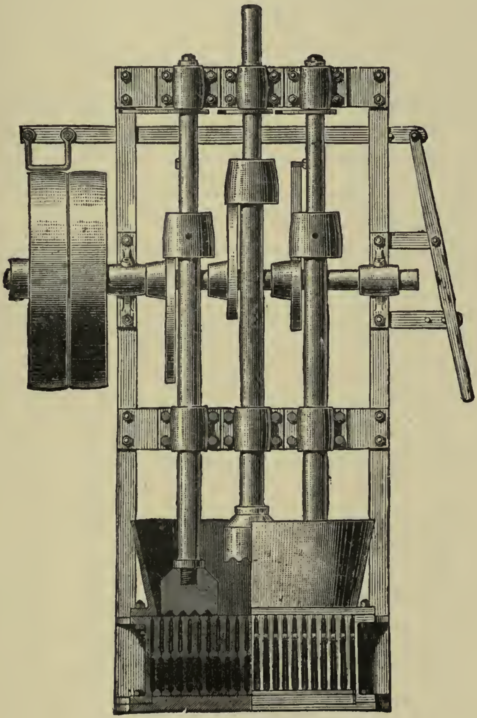


Fig. 1.—Braun's Crusher.

Crushing Machine.—Fig. 1 shows a crushing mill as is generally used, and it will be seen that it has three pounders or crushers, which are alternately lifted and allowed to fall on to the raw material that is thrown into the receiver at the base. Before being thrown into the mill, the petroleum coke or gas retort carbon is thoroughly cleaned by hand by means of wire brushes, so as to take away any particles of sand, &c., that may have got mixed with it through handling or transportation. Petroleum coke is generally clean, while gas retort carbon, as it arrives in the factory from the gas-works, is not all serviceable for carbon production; it must generally be assorted, as some parts of a piece will be found to consist of a sort of burnt porous material, while the other part is of a hard solid material. Carbon manufacturers take this hard part, which has either a black or grey lustre, and resembles graphite; in fact, many carbon makers call it gas graphite. These parts are usually knocked or chipped off with a hammer, while the remaining portion which is not used for the carbon is thrown into the boiler house for furnace consumption. The crushing or stamping mill breaks and crushes the clean and assorted raw material into small pieces which pass through the steel grate, as can be seen in the illustration. This grate can be adjusted so as to allow pieces of any desired size to pass, and generally it is so set that the raw material is broken into pieces about the size of small gravel. There is no doubt that the kind of breaker shown in Fig. 1 is one of the most advantageous machines of its kind in the manufacture of carbon products, as it prepares the material to be ground in other machines, and saves much wear and tear in these machines. Yet it is almost impossible to believe that some carbon manufacturers are without this crusher, and the author has seen a factory where they throw the raw material into a sort of centrifugal breaker or crusher, that of course breaks and crushes the raw material into a much finer state than the machine mentioned above does, but the wear and tear on these centrifugal machines is something terrible when much work is required of them. As gas retort carbon and also the petroleum coke are very hard—in fact, some pieces will cut glass—it is plainly evident that when such a material is to be divided into a fine state it must undergo several successive operations before it is reduced into powder. To throw large pieces into a machine and expect it to come out ground up is out of the question. Apart from the wear and tear mentioned above, there is this one great objection to such hurrying processes—that the wear and tear does not only mean the expense of renewal, but the particles of metal that are worked off get into the carbon, which as every engineer knows is very detrimental to a good working lamp. The author has seen carbon powder or flour, into which a horseshoe magnet was stirred, and when withdrawn was full of iron particles. Such material will never make good electric light carbons. To obviate such difficulties the raw material should be broken gradually into smaller and smaller parts in machines properly designed for the purpose.

Magnetic Separator.—Some manufacturers use a magnetic separator after the material has been ground down to a powder, to insure against iron particles that may have become mixed with the carbon. As this process is not expensive it can be recommended as a safeguard. Inexpensive magnetic separators, similar to those first designed by T. A. Edison, can now be obtained. The following are the dimensions of the crushing mill :—

Height of the mill with pounder-up		2,350mm.
Length, including pulleys (fixed and loose)		1,500 „
Breadth		800 „
Diameter and width of pulleys	680mm.	by 120 „
Weight of the whole mill	about	1,120kilo.
Revolutions per minute	about	45 to 50
Horse-power required to drive the mill	about	2

The crushing mill should be placed on a good and solid foundation, so as to prevent vibration to the injury of neighbouring buildings.

If petroleum coke has been crushed, it is then taken and packed into retorts, which are sealed up in order to prevent combustion, with the exception of a vent or two to allow for the escape of the gases which arise from the volatile matter and water when the coke is heated to incandescence. As already mentioned above, petroleum coke when calcinated loses about 30 per cent. of its weight, and it is thus necessary to calcinate it first before working it into carbons, which would otherwise, when baked, be porous. If a well-adapted furnace is built especially for calcinating the raw material, it will do its work in 10 to 12 hours ; in fact, it can be done in less time, as the raw material does not need to be heated gradually, as the carbons do in order that they may not warp, for in the raw material no consideration can be taken in regard to warping or shrinkage, as it is of no account.

The principle on which a calcinating furnace should be built is the Siemens regenerative plan. It may be said that calcinating by means of retorts is expensive, but the author can only say that when a good carbon is desired the method of using retorts or troughs, either for calcinating or baking the carbons, is the only sure and reliable way, and in the end the cheaper, while the handling is convenient. Some manufacturers pile their material and also the carbons into the furnace, cover them up with carbon dust and chamotte slabs. On this pile the flames are to act on all sides, but it will be shown later that this single furnace system is a thing of the past for modern makers, and that firms who continue to use such furnaces cannot expect to compete successfully, either in quality or commercially, with makers who use the modern furnace. One of the main things in the manufacture of carbons is the *furnace*, and no doubt therein lies the secret that has baffled many in their attempts to produce a good carbon.

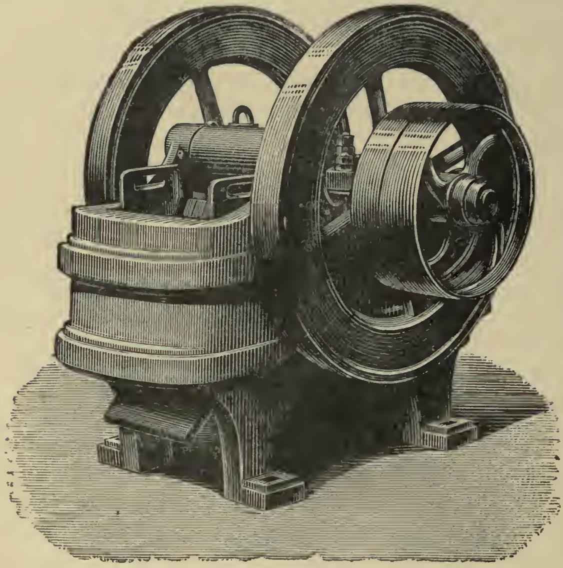


FIG. 2.—Braun's Graphite Breaker

Many have worked upon the system of preparing the raw material, thinking the secret of a good carbon must be in the selection of some special material, whereas it may be simply stated that one of the most vital necessities in the production of a good carbon is the furnace, and that, although good material may be used, if the furnace in which the carbons are baked is not adapted to the requirements the carbons will not be up to the standard quality demanded in these days.

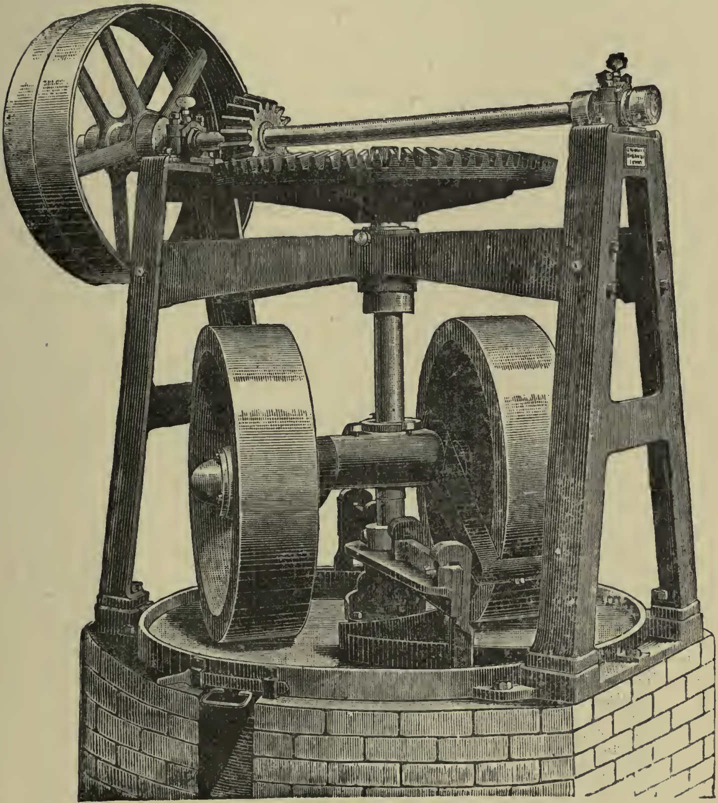


FIG. 3.—Braun's Crushing Mill.

After the petroleum coke has been baked, or calcinated, care should be taken that the retorts with their contents have cooled down sufficiently before the raw material is taken out.

When taken out of the retorts it will be found to appear dry and crisp, having a grey, metallic appearance, and if pure or of good quality it does not cake.

Fig. 2 represents another kind of crusher or breaker, made by J. C. Braun especially for gas retort carbon, in which the cheeks can also be adjusted to break the raw material into various sizes, while at the same time they can be easily replaced when damaged. The machine is made in two sizes. On the whole, however, the writer prefers the crusher shown in Fig. 1 for breaking the petroleum coke or gas retort carbon. The gas retort carbon need not, of course, be calcinated if dry.

Crushing Mill.—The material, after having passed the crushers (petroleum coke being already calcinated) is passed on to the crushing mill with vertical runners, shown in Fig. 3. This, as will be seen, resembles somewhat the old-fashioned mills used in grinding corn. The mill consists of two heavy vertical runners connected together by an arm that is rotated from the vertical shaft, to which power is communicated by means of a bevel gear, as shown. To the vertical shaft are also attached two scrapers that mix and stir the material, pushing it constantly into the path of the runners. The following are the dimensions of the mill:—

Diameter of the vertical runners		1,000mm.
Width ,, ,, ,,		250 ,,
Diameter of the grinding surface on which the runners revolve		1,600 ,,
Length of mill, including pulleys		2,200 ,,
Height up to tip of pulley		2,150 ,,
Width of mill		1,650 ,,
Diameter and width of fixed and loose pulleys		980mm. by 160 ,,
Revolutions of the pulley per minute		72
Horse-power required to drive mill	about	5
Weight of complete mill	,,	3,900 kilos.

Another neat crushing mill is shown in Fig. 4, made by F. Pemsel. The material is taken away from this machine from time to time and passed through a sieve, the fine or ground part being passed into the rolling mill, while the coarse part is returned to the mill with the vertical runners.

Sieving.—Fig. 7 shows a rotary sieve designed by the author after the style of a similar machine designed and made by A.

Zemsch, which has a decided advantage over the hand-sieves generally used in carbon factories. It consists of a wooden frame or box, *w* (which may also be of metal), having a receiver, *d*, at one end, into which the material to be sieved is thrown. At the bottom of the frame *w*, or rather at the middle of its length, a sieve is attached, in a semi-circular form, not shown in the figure. That portion of the sieve over the box *a* is a very fine one, having about 90 meshes to the linear inch (or about 8,100 per square inch), while that one over the box *b* is coarser, having only about 15 to 20 meshes to the linear inch (about 225 to 400 per square inch), while over the box *c* there is nothing at all. The boxes *a*, *b* and *c* are made of sheet-iron, and slide under the mouth-pieces *i*, *i*, *i*. Passing through the centre of the frame is a shaft, *g*, which rests in the bearings *k*, *k*, and is provided with a fixed and loose pulley, *e*, *e*. A wooden cylinder, *h*, is fixed on the shaft *g*, as shown, and on this

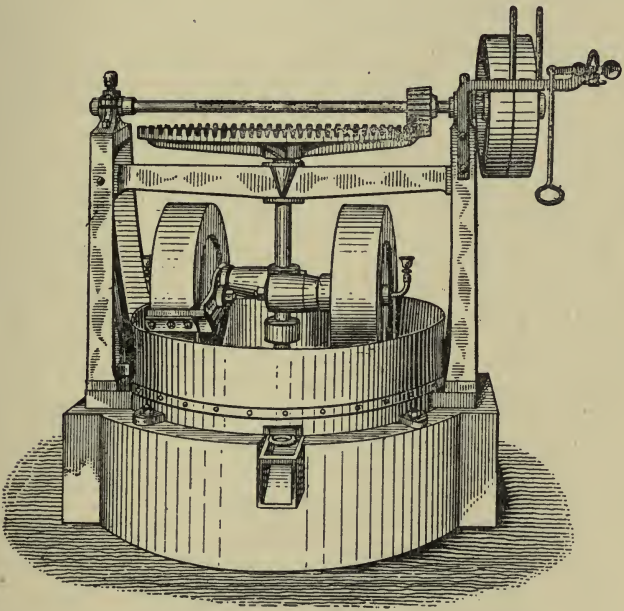


Fig. 4.—Pemsel's Crushing Mill.

wooden cylinder there is attached a sort of Archimedean screw made of sheet-iron. On the rim of this screw is fastened a tapering brush made of bristles, which when revolving (at 40 to 50 revolutions per minute) always keeps the meshes from getting clogged up. It will be seen that when the material after having passed the mill, shown in Fig. 3, is thrown into the sieve at *d*, it falls down, and the action of the screw is to keep pushing it on towards the opposite end of the sieve. The fine particles fall into the box *a*, while the coarser grains are pushed on and fall into the box *b*, and the still coarser pieces are pushed into the box *c*. By this means the material can be assorted, as the fine part or powder that falls into the box *a* need not undergo any more milling, the material that falls into the box *b* is passed over to the roller mills, shown in Figs. 5 and 6, while the material that is pushed into the box *c* is again thrown into the mill with the vertical runners (Fig. 3).

Roller Mill.—The material passed through the roller mills (Figs. 5 and 6) is ground down until it has about the same fineness as that which has passed the sieve at *a*. These machines have cylindrical rollers of chilled steel, which can be adjusted so as to grind the material down to any degree of fineness. The following are the sizes generally used by carbon manufacturers:—

Roller Mill Number	1	2	3	4	5	6
Number of rollers	2	2	2	4	4	4
Length of rollers .. ...in mm.	300	400	500	300	400	500
Diameter of rollers ... „	230	230	230	230	230	230
Length of machine ... „	925	1,050	1,165	1,180	1,290	1,400
Width of machine...... „	725	850	940	1,300	1,300	1,300
Height of machine ... „	1,330	1,360	1,400	1,400½	1,400	1,400
Horse-power required...about	1¼	1½	2	2	3	4
Weight ....in kilos.	760	850	1,050	1,200	1,300	1,400
Diameter of pulley ... „	400	400	450	400	400	450
Width of pulley ...... „	110	110	120	110	110	120
Revolutions ....per minute	250	250	250	250	250	250
Output, per hour, in grinding pieces of about 1½mm. into flour ....in kilos.	60	75	95	120	150	200

Some manufacturers then store the material, after it has passed the machines mentioned above, in the bins of the store room. There are some, however, who sieve the ground

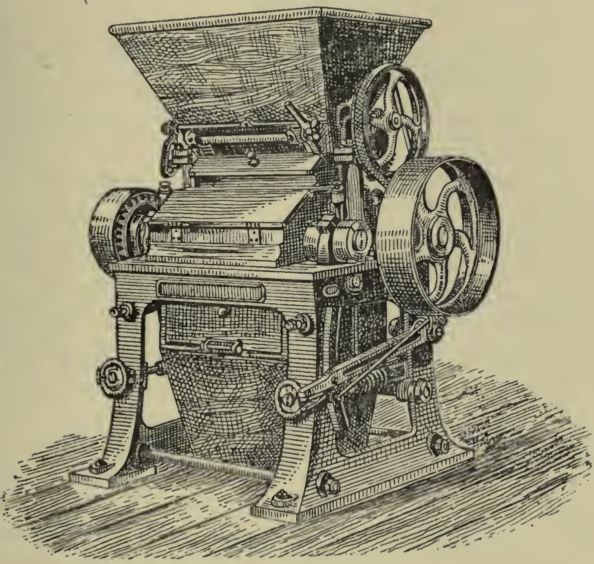


Fig. 5.—Braun's Roller Mill.

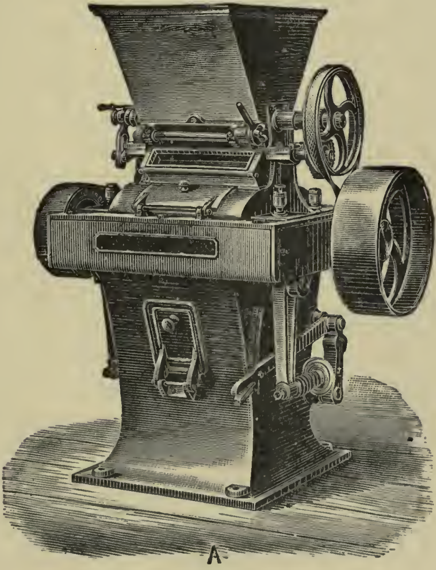


Fig. 6.—Pemsel's Roller Mill.

material for the last time through a rotatory silk gauze, and thus obtain a carbon flour as fine as can be demanded. That part of the material which does not pass the silk gauze is subjected again to a second grinding in the roller mills, and then passed through the silk gauze. There is no doubt that this last sieving through the silk gauze insures a perfect and evenly-divided material for the manufacture of high-grade carbons, especially for alternating carbons and those that are used in enclosed arc lamps, as any difference in the grain of the material often has a prejudicial effect on the carbons when finished and used in the lamp.

How the raw material—that is, the petroleum coke or gas retort carbon—is ground and prepared for use has now been fully explained, but the author has known cases where the lampblack has been mixed with tar and then pressed into cylindrical balls, which are afterwards calcinated. After being calcinated this material must undergo the same process of grinding as previously explained. The largest and most celebrated carbon factories of Germany do not, however, calcinate their lampblack, as a good dry lampblack needs no calcinating. Those factories, however, that have not the modern furnace, soon find out that when carbons are made of lampblack which has not been calcinated they are working a material that is very brittle and does not burn well in the lamp, and thus they have recourse to calcinating their lampblack first, as Carré did, thus obtaining a fair carbon, but by no means a high-grade one. The gradual, high and even heat of the modern carbon furnace saves calcinating the lampblack, and at the same time produces the best carbons. It is always well, as a matter of precaution, to sieve the lampblack as it arrives, because it often happens that foreign matter gets mixed with it, such as grains of sand, nails, &c. To sieve the lampblack it is well to use a sieve similar to that shown in Fig. 7, as the bristle brushes keep the sieve clean and prevent the lampblack from clogging up the meshes. Lampblack, of course, needs no grinding, as it is always in a finely-divided state.

Bin Room.—The store room in which the ground material, or let us say the carbon flour, is stored, is, in large factories, usually a room above the mixing department, and the only one. Carbon factories are built nowadays all "parterre," with no floors above the ground floor. They are generally situated on the outskirts of cities, or in some favourable place in the country where labour and power are cheap, and where there is good railroad connection. A large carbon factory should also have its own lampblack works, and as such works are a nuisance near a city or dwellings on account of the soot that escapes, they are generally built in the open country, or in a forest, as in Germany. The store room where the carbon flour is stored is generally divided into compartments by means of boards, the spaces or bins of which are filled with the carbon flour. There is a space or bin for the lampblack, for the petroleum coke, and one for the gas retort carbon. From each bin there is a spout that leads to the mixing department, which is, as already mentioned, underneath the bins. The spouts are provided with gates by which the flow of the flour can be controlled. The material is generally tapped off by means of bags that are drawn over the mouth of the spouts, which thus prevent the carbon flour from escaping.

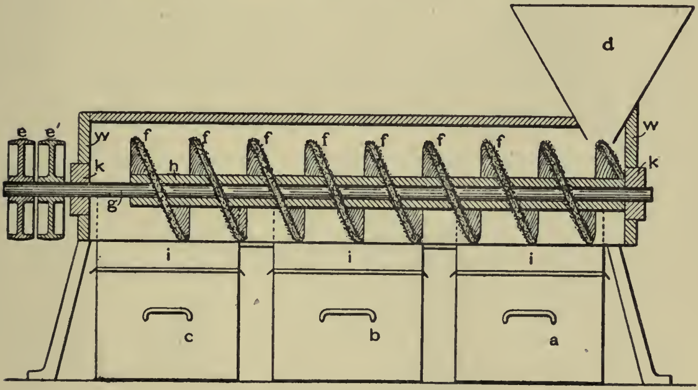


Fig. 7.—Jehl's Assorting Sieve.

Mixing.—It was formerly common to mix the dry materials in a machine called the "dry mixer," an illustration of which is shown in Figs. 8 and 9. Some manufacturers still do this in the case of second-grade carbons. These machines consist simply of a closed sheet iron barrel having a cover at the top, into which the mixture is thrown. At the centre there enters

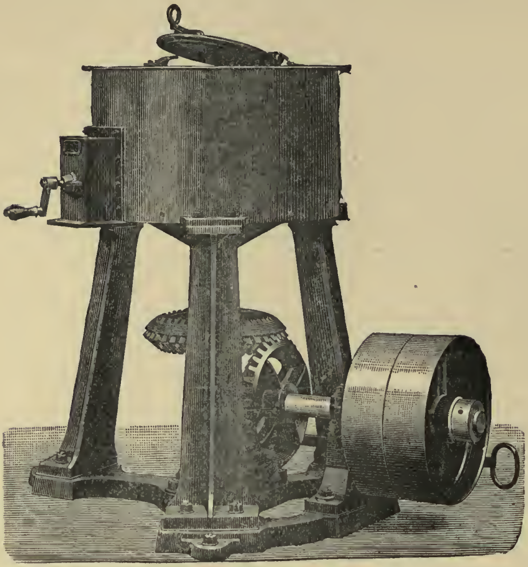


FIG. 8.—Braun's Dry Mixer.

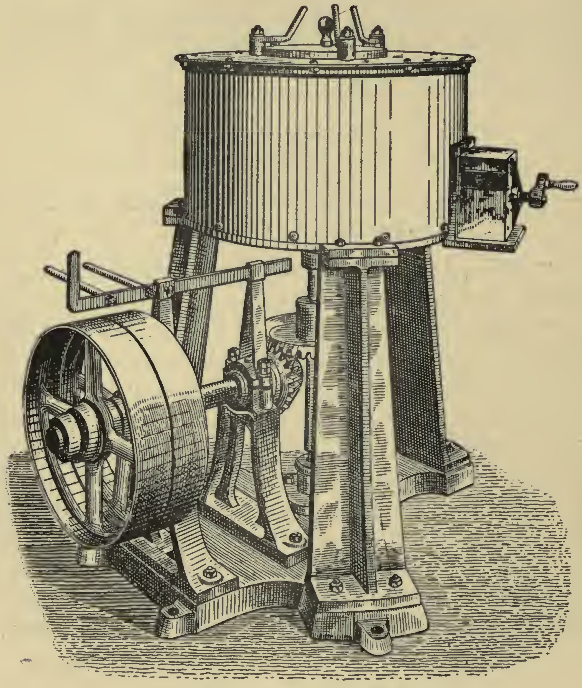


FIG. 9.—Pemsel's Dry Mixer.

from the bottom a vertical shaft, to which revolving vanes are attached to mix up the carbon flour. The vertical shaft is worked by means of a bevel-gear as shown.

The mixed material is discharged from the box at the side of the barrel. The dry mixers have generally the following size and dimensions :—

Height of the machine with the cover down	1,300mm.
Length ot the machine including pulleys	1,500 ,,
Width of the machine	1,150 ,,
Diameter of fixed and loose pulley	440 ,,
Width ,, ,, ,, ...	120 ,,
Revolutions per minute..	120
Horse-power required to drive machine ....about	½
Weight of complete machine	550kg.

Some carbon manufacturers have already discarded the dry mixer, as they find that the "wet mixer" answers the same purposes, and that time is thereby saved. Then again, it must be remembered that there is a general tendency nowadays to make only high-grade carbons, and, as has been already shown, these carbons are made wholly of lampblack, which needs no mixing except with tar. Therefore the dry mixer is seldom used now, and when a mixture is made of several kinds of carbon flour they are mixed and kneaded in the wet mixer. Fig. 10 shows such a wet mixer made by J. C. Braun under the patents of Werner and Pfleiderer. These machines were formerly built with a progressive and retrograde motion, but they are now generally only made with one motion. The essential part in these wet mixers or kneaders is the rotation of zig-zag blades between which the material gets squeezed and kneaded. The following different sized machines are made :—

Machine No..............................	I.	IA.	II.	IIA.
Length of machine............in mm.	1,250	1,250	1,550	1,800
Width ,, ... ,,	920	1,160	1,100	1,230
Height ,, ... ,,	1,400	1,430	1,750	1,780
H.-P. required to drive machine ...	1½	2½	2½	3½
Diam. and width of pulley...in mm.	405 × 200	560 × 240	560 × 240	670 × 330
Weight of machine ....in kilos	360	480	750	900
Revolutions ....per minute	120	120	120	120

A few words concerning tar, which is used as the binding material, in order to be able to work the carbon flour into a plastic mass, will not be out of place here. When coal is decomposed in closed vessels, from which the air is excluded, as in the retorts in gas works, large quantities of volatile matter is expelled, partly in the form of gas and partly in the form of vapours, which when cooled down become liquids or solids, while there remains in the vessel or retort what is known as gas-retort carbon. The vapour part, after condensing, will be found to consist of water and different hydrocarbons, generally called gas naphtha; in this liquid there is also a considerable quantity of a black viscous matter known as coal tar. This is the tar that is used in carbon manufacture nowadays, and its function is simply to get the carbon flour incorporated, so that it can be worked and kneeded into a plastic mass. Formerly some makers used sugar or molasses, and it is related that one manufacturer tried the whites of eggs as a substitute, but soon found that these *omelettes à la charbon*

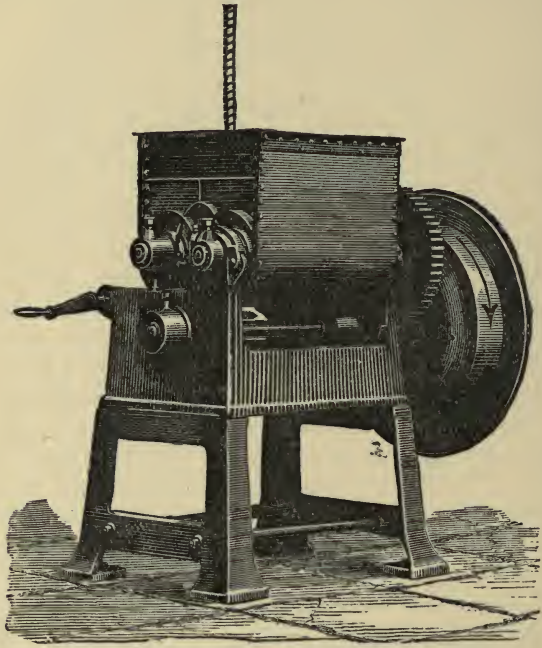


FIG. 10.—Braun's Wet Mixer (Werner and Pfleiderer Patent).

were no good. Tar seems to be the best material for this purpose of binding or incorporation, as with it the mass can be worked well. Of course, in using the word plastic the author does not mean that so much tar should be mixed with the carbon powder that it can be kneaded like baker's dough, as a mixture of that consistency would be squirted out of the press with very little pressure, while the carbons, when baked, would be porous. The amount of tar mixed with the carbon flour, as has already been mentioned, is from 25 to 30 per cent., and this mass, after having been kneaded, hardly seems sticky; in fact, it is easily broken into chips. Great care should be taken to use only tar that is dry, as common tar generally contains water. Carbon factories generally have a large tank, into which they empty the tar as it arrives in barrels. This tank is heated by means of pipes using exhaust steam, and the water, if any be present, will soon settle at the bottom, where it can be drawn off by means of a faucet placed near the bottom. The heat from the steam worm also drives off the lighter oils sometimes contained in tar. These oils are not required in carbon making, as they volatilise at a low temperature, and the great object to be attained in carbon mixtures is that the whole should if possible become carbonised when baked, and should not possess any volatile matter, as matter that volatilises out of the carbon mass makes it less dense and more porous. Good dry tar can also be obtained in commerce, but it is always well to take the precautions, mentioned above. From the tar tank a pipe is connected which leads into the mixing room and flows into another small tank or reservoir. Such a reservoir is shown in Fig. 11. This contains a steam worm, *b*, which heats up the tar, and only heated or warm tar should be used for mixing, the results obtained in the wet mixer being far more satisfactory when warm tar is used. It incorporates better with the carbon flour or lampblack, because obviously in the warm state tar is much less viscous than when cold.

Tar Reservoir.—In Fig. 11, A represents the reservoir, *a* the stop cock by which the tar can be drawn off into buckets when required, while *c* and *c*′ are steam valves by which the steam can be regulated or cut off. The pipe that connects this reservoir with the large tank is not shown in the figure, but it may be connected at any spot. If the large tank is below the level of the reservoir the tar must be pumped up into it. Pipes that have a diameter of not less than 2½in. should be used. The small reservoir may be about 1,000mm. high and about 700mm. diameter with a tapering end as shown.

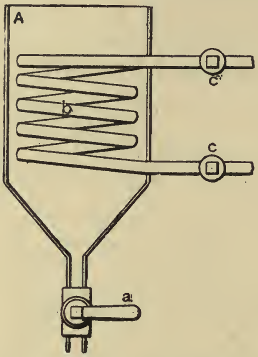


Fig. 11.—Small Tar Reservoir.

Kneading.—After the material has been well mixed in the wet mixer it is subjected to some further kneading. Some manufacturers use machines with vertical runners similar to the one shown in Figs. 3 and 4 for kneading. The kneading is, however, now mostly done with the roller mills shown in Figs. 5 and 6, the cylinders or rollers of which are adjusted for the purpose. Some works have also what is known as "calender presses," which are machines similar in principle to the roller mills. They contain generally two sets of long rollers through which the material is forced and which knead it. These calender presses and the roller mills are no doubt the best for kneading, and this fact is now recognised.

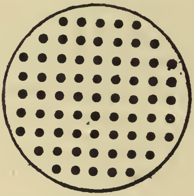


Fig. 12.—Draw-plate for Kneading Carbon Mixture.

Some firms also press the mixture into balls of cylindrical shape about 150mm. diameter and 300mm. long, which are squirted through a draw-plate with a large number of holes, as shown in Fig. 12. This draw-plate is made of steel, and the holes have about 5mm. diameter and a tapering

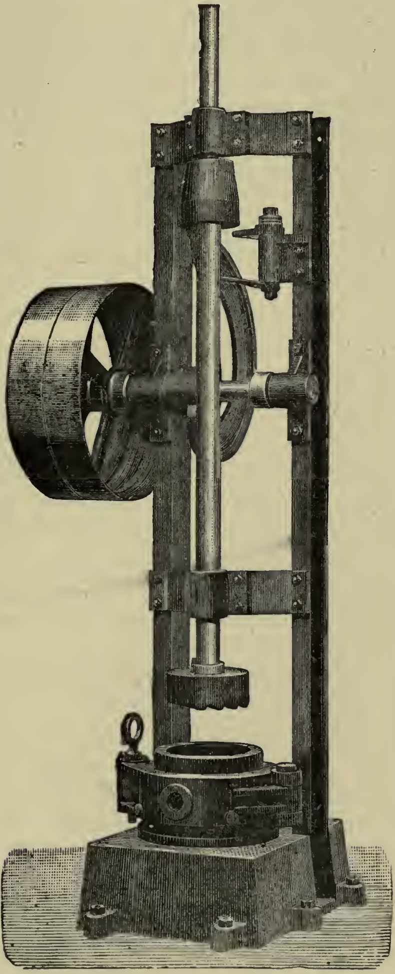


FIG. 13.—Form or Cake Pounder.

mouth on the side from which the pressure is exerted, so as to ease the passage of the material that is forced through. The material emerges from the holes in worm-like form, in fact, looks as if innumerable black worms were issuing from the plate. There is no doubt that forcing the material through such a draw-plate has a tendency to help the kneading process, which then takes place as the material is passed through the calender presses or roller mills. The author thinks that most manufacturers, however, knead their material only through the roller mills, calender presses, or similar machines. As already stated, the mill with the vertical runners was also formerly used for kneading, but is now being discarded.

Cake Pounder.—After the material has been well kneaded it is taken to the "form pounder," which is shown in Fig. 13. This machine, as will be seen, consists of a form that is divided into two parts, which can be opened by pulling out the pin at the side. Into this form the kneaded material is put, and the pounder over it stamps the material into cakes that fit into the cylinders of the hydraulic presses. The pounder shaft is actuated by a sort of eccentric arm, which is driven from the pulley shaft. These machines form a valuable adjunct to a carbon factory, as they pound the material into solid cakes, which are then pressed again into cakes of greater length by the hydraulic advance presses.

Hydraulic Press.—By advance press is meant a hydraulic press that is generally used by carbon manufacturers for pressing the kneaded material into cylindrical forms, called in Germany "ballen"; but the writer prefers to use the term "cakes" instead of "balls." The following are the sizes and dimensions of the Braun type of pounders:—

Cake Pounder No.	1	2	3
Diameter of cakes ....in mm.	250	700	700
Height of cakes .... "	250	250	750
Height of machine with raised pounder "	2,970	4,400	4,500
Length, including pulleys .... "	970	2,000	2,000
Width of machine .... "	950	1,600	1,850
Width and diameter of fixed and loose pulleys.......................... "	680 × 120	1,200 × 200	1,600 × 180
Revolutions per minute	35 to 40	30	30
Horse-power required....................	1¼	4	5
Weight of complete pounder.....in kilos.	840	5,250	7,000

Pounder No. 1 is suitable for the hydraulic presses Nos. 1 to 4, as the dimensions of the cakes fit their cylinders, two cakes being required to fill the cylinder. Pounders Nos. 2 and 3 are adapted for the larger hydraulic press No. 5, the cylinder of which requires three cakes of pounder No. 2 and one cake of pounder No. 3.

The carbon cakes after being finished in the pounder are taken to the advance presses and pressed into finished cylindrical cakes, which are then ready to be squirted into carbons by the carbon presses. The pressure used nowadays is generally from 350 to 400 atmospheres (water pressure). Fig. 14 gives an illustration of a hydraulic press used in carbon factories, connected to its press pump, which has five cylinders. In the figure *a* is the cylinder into which the water is pressed by the pumps, the pressure of which acts on the ram *r*, which works or presses into the cylinder *b*, charged with the carbon cakes. The ram can be made to advance, recede, or can be stopped by means of the wheel *c*, which operates valves on its sides, depending upon the direction in which it is turned. Those parts of the press that are subjected to heavy strains are made of the best steel, while the water cylinder is fitted with a liner of bronze to prevent rusting. The cylinder *b*, into which the carbon cakes are put, is provided with a steam jacket which keeps it warm, and the heat acts on the surface of the cakes, establishing a sort of lubricating action that helps the passage of the material when forced out. There is also attached to the press a safety valve, or device, that prevents the ram from travelling further, either forwards or backwards, than its normal path. The starting of the ram either forwards or backwards is effected through the action of all the pistons of the press pump. Some of these presses have also a regulator valve placed between the press and press pump, by which the velocity of the ram can be varied when going forwards or backwards.

The following are some of the various types of the Braun hydraulic presses and press pumps used in the most important carbon factories in Germany: Press 1 is a simple press that squirts only carbons of a less diameter than 18 or 20mm., and most large carbon factories have a few presses of this type. This hydraulic press is driven by a press pump

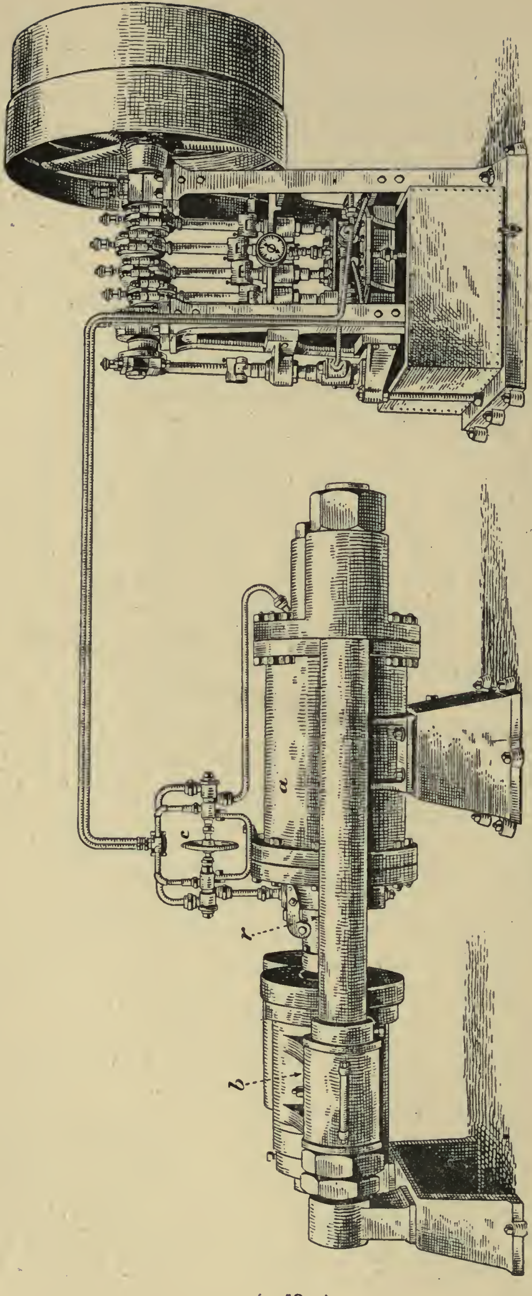


Fig. 14.—Braun's Hydraulic Press and Press Pumps.

having three cylinders. Press 1A is a duplex hydraulic press, as it contains two cylinders on either side of the water cylinder or ram. While the ram is working in one direction, and pressing the carbon mass out, the other cylinder is being charged, and thus the object is to keep the press constantly going and not to lose any time, as in other presses, which must be stopped when a fresh charge is given. However, there is not such a saving of time in practice as might be supposed, and Press 1 is, on the whole, more economical in actual use. This press is also worked by a triple-cylinder press pump. Fig. 15 shows a duplex hydraulic press, made by F. Pemsel, which works with a maximum pressure of about 400 atmospheres, while the dimensions of the cylinders that receive the carbon cakes are 650mm. long and 90mm. in diameter. The cylinders, it will be seen from the figure, can be turned on their vertical axis, which facilitates charging. The whole press weighs about 3,300 kilos. Press 2 is an advance and carbon press combined—that is, it can be used to press the cakes coming from the pounder, and can also be used for squirting carbons. It presses the cakes that fit the cylinders of Presses 1 and 1A. This press is worked by a four-cylinder press pump. Press 3 can also be used as a combined advance and carbon press. It squirts larger size carbons than No. 1 or 1A, and can also be used to make battery plates, brushes or small-sized electrodes. This press is worked by a five-cylinder press pump. In Fig. 16 we have a very neat design of a hydraulic press that can squirt carbons from 12mm. upwards. This press also works with a maximum pressure of 400 atmospheres, while its receiving cylinder is 600mm. long and 250mm. in diameter, thus taking about 35 kilos. of carbon material at one charge. When a charge is inserted into the cylinder this is turned on its vertical axis, which permits of easy handling. The cylinder is also provided with a steam jacket, as shown, and the press, complete, weighs about 4,000 kilos.

Press 4 is an advance press, and serves only to press the carbon cakes that come from the pounders so as to fit the carbon cylinders of the presses that squirt the carbons. It is advisable for carbon makers to use advance presses for the pressing of carbon cakes only, and presses that are specially

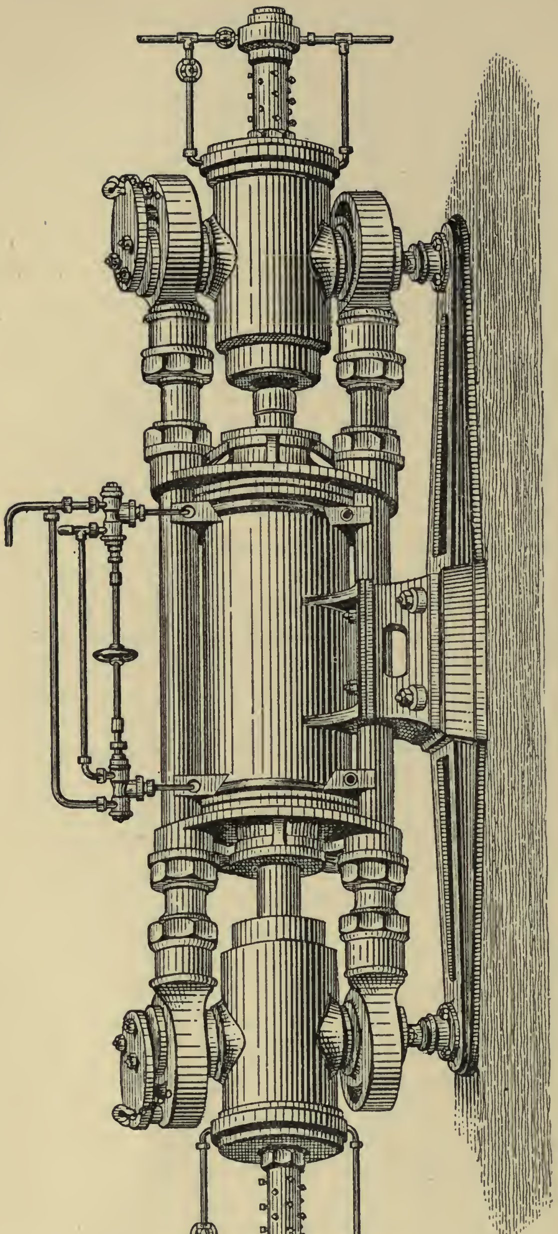


FIG. 15.—Pemsel's Duplex Hydraulic Press.

designed for the purpose for squirting carbons. A small factory may use a combined press, but a large modern factory should have separate presses for the different kinds of work performed. In working Presses 2 and 3 for pressing cakes a different speed is required for the press pumps than when squirting carbons. Generally a large carbon works has three or four advance presses and four or five presses that squirt carbons or electrodes. Press 4 is worked by a press pump that has five cylinders. Press 5 is a large machine, which can make electrodes having a breadth of 500mm. and a thickness of about 100mm. This press can also press the carbon cakes that are used in all the other presses for squirting carbons, but is generally only used for pressing or squirting large battery plates, electrodes for electro-chemical and smelting works, and in fact, for all large sized work. This press should be installed by all makers who desire to extend their carbon industry in all its branches and do not wish to confine themselves to electric light carbons only. The electrode industry will no doubt be a large one very soon, and the demand for that article will be considerable, so that the author would advise firms starting in the carbon business to see that such a press is included in their equipment. This press (No. 5) is also worked by a five-cylinder pump. It may be here again mentioned that when it is desired

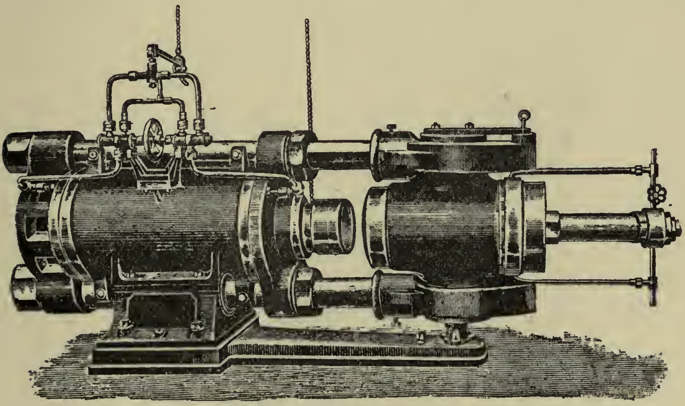


Fig. 16.—Pemsel's Hydraulic Press.

to manufacture articles of carbon having an uneven contour or size, they must be pressed through a plunger press. Steel moulds are made to the shape of the article to be manufactured, and these are filled with the carbon material and placed in the plunger press, the ram of which compresses the material in the moulds or forms. The forms are then taken apart and the compressed article taken out. Generally, several forms are placed in the press at one time. However, these plunger presses are seldom used in carbon works, as such works generally manufacture articles of carbon that can be squirted. The press pumps, one size of which is also shown in Fig. 14, are made of the best material—the

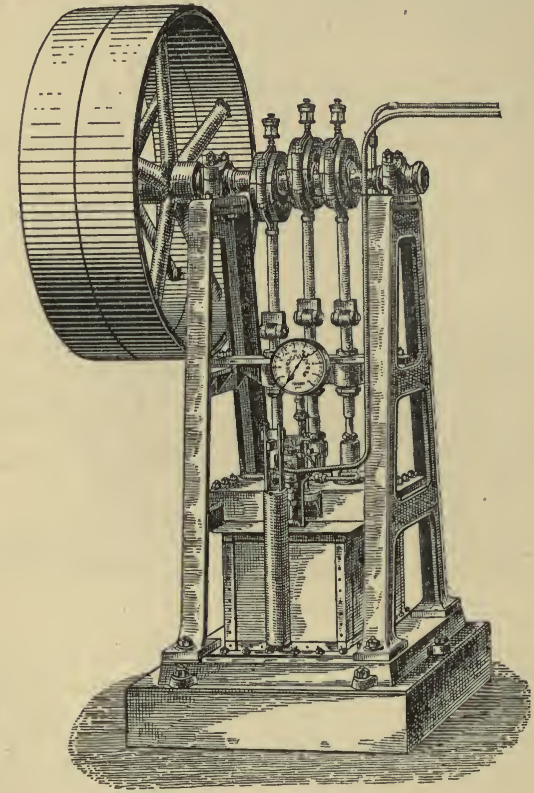


Fig. 17.—Braun's 3-cylinder Press Pump.

pump cylinders either of steel or phosphor-bronze, the valves and valve-boxes of the latter material. The eccentrics and eccentric rods are of steel. Each press pump has a fixed and loose pulley. Press pumps that have pistons of different diameter are generally so constructed that the piston having the larger diameter is released from action when the pressure is raised above 25 atmospheres, and when the pressure falls below 25 atmospheres it resumes work. The object of this larger piston is to pump and deliver the greater part of the water that is needed to fill the water cylinder of the hydraulic press, which would take more time if done by the smaller pistons alone. Each press pump is provided with safety valves and a manometer gauge that shows the pressure of the water. Fig. 17 gives a general view of a Braun three-cylinder press pump. The following table gives some of the sizes and data concerning Braun hydraulic presses and pumps:—

No. of hydraulic press	1	1a	2	3	4	5
Length of press ....in mm.	2,900	4,800	3,000	3,200	3,600	4,350
Width of press .... „	1,300	1,300	1,500	1,750	1,800	2,750
Height of press .... „	1,450	1,450	1,500	1,650	1,650	1,800
Weight of complete press (kilos.)	2,300	3,100	3,850	5,850	8,000	15,600
Press Pumps.						
No. of cylinders	3	3	4	5	5	5
Diam. of low-pres. piston in mm.	52	52	60	70	70	70
Diam. of high-pres. piston „	26	26	30	30	35	35
Stroke of low-pres. piston „	60	60	60	110	120	120
Stroke of high-pres. piston „	60	60	60	60	75	75
Max. pressure for large piston...	25	Atm. 25	25	25	25	25
Max. pressure for small piston...	400	400	400	400	400	400
L'ngth of pump with pulleys in mm.	1,160	1,160	1,400	1,550	1,550	1,600
Width of pump	1,180	1,180	1,200	1,200	1,200	1,200
Height of pump to centre of pulley	1,565	1,565	1,550	1,550	1,550	1,575
Diameter of pulleys ......in mm.	1,165	1,165	1,200	1,200	1,200	1,500
Width of pulleys .... „	200	200	220	250	250	270
Revolutions per minute............	50–70	50–70	50–70	50–80	50–80	50–80
H.P. required to drive pump ...	3	3	7	10	12	19
Weight of pump in kilos	920	920	1,300	1,760	1,780	2,000

Fig. 17A shows a well-constructed press pump made by F. Pemsel, which contains a differential safety valve, a detail drawing of which is shown in Fig. 18. These press pumps are made with one piston of 60mm. and two, three, or four pistons of 25mm. diameter each, their stroke being 65mm. The high-pressure cylinders of the pump cease to act when

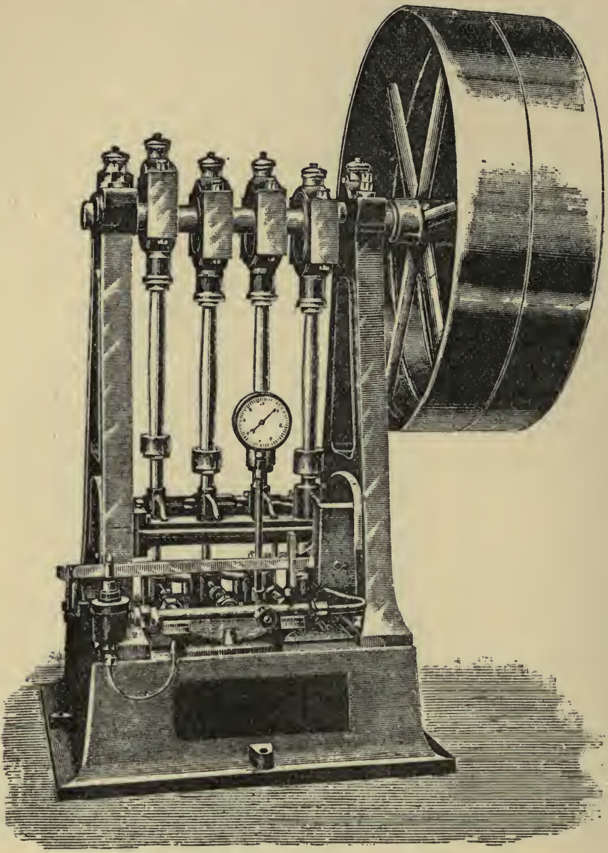


FIG. 17A.—Pemsel's Press Pump.

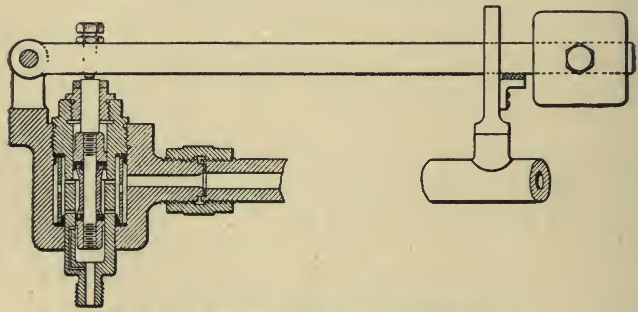


FIG. 18.—Pemsel's Differential Safety Valve.

the maximum pressure ot 400 atmospheres is obtained, while the low-pressure ones stop working at 50 atmospheres. The diameter of the pulleys is 1,180mm., while their width is about 185mm., making about 60 revolutions per minute when working. The water reservoir is made of cast-iron, and has a capacity of about 250 litres, while the high-pressure cylinders are of steel mounted with bronze, the low-pressure ones being entirely of bronze. The weight of the whole pump is about 1,100 kilos.

Squirting Carbons.—We see, thus, that electric light carbons are squirted out of the press at a very high pressure; for with a maximum water-pressure of 400 atmospheres the cylinder containing the carbon cakes received a pressure that is nearly 1,100, that of Press 3 about 900, and that of Press 5 about 200 atmospheres. Press 1 can squirt out about 40 kilos. of material per hour, Press 2 about 120 kilos, Press 3 about 150 kilos, and Press 5, when making electrodes or large carbon plates, about 1,500 kilos. The velocity with which carbons are squirted out of the press per minute varies between 8 and 10 metres, as it depends upon the diameter of the carbons being squirted. It must be remembered that Press 1 is used for carbons of small diameter, the sizes generally used in practice, while Presses 2 and 3 are used for larger size carbons, from 18mm. upward. Of course there are more kilogrammes of material per hour squirted out of the presses that make large size carbons, electrodes, &c., than those that squirt small size carbons. Carbons of small diameter can also be squirted out of Presses 2 and 3, but in that case the valves of the press must be only partly opened, or else the velocity with which the carbons are squirted will be too great. It is, however, best to use only a machine or press to do the work it is designed for, and not to expect it to do all kinds of work, as every machine, engine or apparatus, no matter in what branch of an industry it is used, has a specified limit to do a certain kind of work, above or below which limit its efficiency is impaired. Hydraulic advance presses that are only used for compressing the carbon cakes as they come from the pounder machines can work off about 180 cakes per press per day of 10 hours. These cakes are then piled in pyramids near the presses that squirt the carbons, &c., and are taken when wanted. They are generally laid on a low platform, so that they do not come in contact with the floor, which is never clean in a carbon factory. The cakes of different mixtures are all piled in their respective places, and it is well to have the low platform divided into compartments for each kind, so that no confusion can arise when taking them away to the press.

Mouthpieces.—When carbons of different diameters are squirted, mouthpieces must, of course, be placed in the presses according to the diameter of the carbon desired. These mouthpieces are generally made of chilled steel, and fit well into the opening made for them in the front part of the cylinder that contains the carbon mass or cakes. It is well to have them long, and when in use to keep them warm. There is generally a sort of steam jacket that provides heat, but in some factories the mouthpieces are heated by means of a Bunsen burner. For a simple solid carbon the mouthpiece has a plain circular boring, according to the diameter of the carbon it is intended for, while, when a cored carbon is made, a three-legged spider, having a long needle screwed in its centre, is inserted into the mouthpiece at the end that is in the cylinder containing the carbon mass. The three legs of the spider stand on a circular ring and slope upwards, coming to a point, and on the inner side of the apex the coring needle is screwed. A flat spider would naturally soon be broken, on account of the great pressure in front of it, whereas one having a pyramidal form acts more like a spear. It is also well to have the legs of the spider with an edge on the outside, which thus prevents the carbon material from pressing too much as the edges cut and push the material aside which is forced to pass through the intervening space between the legs and out of the mouth piece. Some manufacturers use a needle for coring that has a plain circular cross-section, others use a star of some form. One object in using these differently-formed needles for coring is to get a larger resistive surface, thereby preventing the core from falling out, which often happens when the carbon is burning, and sometimes even in transportation. The falling-out of the core is, however, mostly due to the slapdash manner in which such carbons are cored.

The cores of carbons vary from about 2 to 4mm. according to the diameter of the carbon, larger carbons having larger cores. As carbons shrink when they are baked, it is necessary to take this fact into account when the mouthpieces are made. The shrinkage depends greatly upon the material used, and, as has already been stated, the best material is that which has very little volatile matter. Good lampblack, well calcinated petroleum coke and tar, which is already deprived of the lighter oils that go over with it in distillation, should only be used. Then, again, the shrinkage depends upon the pressure at which the carbons are squirted, and the temperature at which they are baked. No definite figure can therefore be given, and the author has seen some carbons shrink 0·1mm. and others 1mm. and more ; it is safe to state that the mouthpieces can be made about 0·8 of a millimetre larger diameter than the size they are intended for, although experience will soon show what constant it is necessary to take. There is another fact to be considered, namely, after the press has squirted out 80,000 or 100,000 metres, it will be found that the bore of the mouthpiece has enlarged, and it will then be found that it is necessary to discard that particular mouthpiece and use it for larger-sized carbons. This grinding out of the bore of the mouthpiece by the carbon mass as it is squirted is observed more when gas retort carbon mixture is used than when lampblack is worked. The mouthpieces, when the bore has been worn, can always be used again for carbons of larger diameters, thus lasting a considerable time. A good stock of mouthpieces should always be kept on hand for all the different sizes of carbons, together with plenty of spiders with needles. The firm's name or the quality of the carbon is generally impressed upon the carbons by means of a small engraved wheel which is placed at the front of the mouthpiece. Some makers also impress the carbons as they are on the cutting table by simply running an engraved wheel with a handle over them; the first method is however to be preferred as it saves time, and makes a better job.

Repair Shop.—It is hardly necessary to state that every carbon factory has a small repair shop attached to its works, and that here the mouthpieces are made and nearly all repairs effected. The repair shop consists of a few lathes of different sizes, an upright drilling machine, vices, a small forge, and the necessary hand tools.

Binding and Packing.—We will now proceed with our carbon-making. The carbon cakes as needed are taken from the low platform where they were piled after having passed the advance press, and are put into the cylinder of the hydraulic press. The ram being in the water cylinder there is plenty of room for this operation. The valve is turned on so that the water can pass into the water cylinder which, pushes the ram forward into the cylinder containing the carbon mass, and the latter is forced out of the mouthpiece. As the squirted carbon issues from the nozzle on an inclined table with a sheet iron pan that is placed alongside of it, the man operating the press breaks it off in lengths of about 1,100mm. to 1,200mm. The rods of carbon roll down the inclined table into the pan, which is taken away when full and another pan substituted. The carbons are then taken off the pan and put on a table covered with a sheet iron plate on which the carbons are rolled, the operater using a flat board for the purpose, as the rods often get crooked in handling. The carbon rods are then bundled and packed together by being laid in the binding form shown in Fig. 19. These forms are usually made of wood and so constructed that the carbons form a six-sided bundle or pack. One of the sides of this binder is adjustable by means of the thumb screws shown in the illustration, so as to fit carbons of different sizes. The bundle is generally bound with iron wire, which is placed in the spaces between the parts of the form in which the carbon rods rest. Flat pieces of carbon are generally interposed between the wire and the carbons so as to prevent the wire from cutting or denting the carbons when bound, as the wire is tightly drawn around the carbons and its ends twisted by means of pliers. The number of carbon rods in a

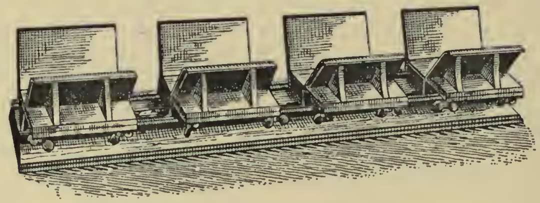


FIG. 19.—Pemsel's Binding Forms.

bundle varies of course according to the diameter of the carbons, the size of the bundles being always the same, as they are usually all placed in retorts of the same size. About 100 or 110 10mm. carbons are contained in one bundle.

After being carefully placed into the chamotte retorts, which are about 1,100mm. to 1,300mm. high, having an internal diameter of about 150mm., and an external diameter of 200mm., the sides and all spaces are filled with carbon dust, which is tightly pounded in by means of a long, light wooden pounder, resembling a flat spoon. If the carbons are the cored variety, the opening at the cores are sealed in order to prevent carbon dust from getting in, which would obstruct the passage to the coring material afterwards. Some manufacturers use plaster-of-paris for this purpose, but the author prefers small wooden conical pegs as more suitable, as they carbonise, and thus do not contaminate the carbon powder used in packing. One object in having the carbons well fixed and solidly packed in the retorts is to prevent as much as possible warping when they are in the baking furnace. The object also in using retorts of such small diameter is to get the carbons well and evenly heated when subjected to the heat of the furnace. This cannot be done otherwise on a commercial scale, and at the same time the handling is easier. There are still a few manufacturers who employ an altogether different system in packing, as they have not yet the modern furnace. On account of this fact they have a hard struggle to compete with the makers who are up to date.

Electrodes, carbon brushes and battery plates, if not of large dimensions, are also carbonised in chamotte retorts if of large size are packed in the oven, and covered with carbon dust and chamotte slabs. However, in the furnace system, which will be described later, it will be seen that furnaces are especially suitable for retort baking, although they are also built with compartments in which large electrodes, battery plates, &c., can be packed and carbonised. Sometimes these modern furnaces are built on a combined system, in which the retorts and compartments are used.

I will now explain the *old method*, which is still in use in one or two factories in Europe, but is, as has already been stated, not commercially equal to the modern way. Although it may appear cheaper at first, it is nevertheless costly in the end. These manufacturers take the carbons as they are squirted out of the press, and break them off also in pieces or lengths of 1,000mm. or so, as previously explained. The carbon rods are then taken to a table, and laid side by side; after which they are cut, while in the soft state, into the required lengths used in practice, by means of a sort of cheese-knife, which the workman runs over the carbon rods, allowance being made, of course, for shrinkage. After this operation has been completed they are taken to the pointing department. The machine in which the carbons are pointed consists of a sort of lathe, in the chuck-wheel of which are held three short knives about 120deg. apart and tapering inwards. In fact, the apparatus somewhat resembles the well-known lead-pencil sharpeners sold by stationers, but has three knives instead of one. In connection with gear-wheels and eccentrics, there is a holder that grips the carbon. This holder works periodically, and when it grips the carbon it goes forward and backward. In going forward it puts the tip of the carbon into the mouth of the pointer, which then shaves off its end into a point, and then recedes. When back into its original position, two small revolving arms pick up the carbon and throw it on to a table, the arms, holder and knives being all in connection with one another by means of gear-wheels. The whole apparatus is a very simple one, and can point about 20,000 to 40,000 carbons in a day. It is obvious that it is easier to point the carbons while in the soft state—that is, before they are baked—and that a man can point more soft carbons than baked carbons in a day, for the latter must be pointed on an emery wheel. An emery wheel can point only about 5,000 carbons in a day, which is one-fifth of what can be done when pointed in the soft state. There is no fault with this system of pointing in itself, but as in the modern system the carbon rods are baked in lengths of 1,100mm. or so, it cannot be applied. The tips of the cored carbons, after being pointed, are smeared up at both ends with plaster-of-paris, in order to prevent the carbon dust from getting in when they are placed in the oven. The carbons are then packed in bundles, which are tied with iron wire in a manner similar to that already explained. The bundles of carbon are not placed in retorts, but are simply piled upon each other in the one chamber that the furnace has. They are then covered with carbon dust which cannot be packed tightly, over which dust chamotte slabs are placed in order to prevent combustion. Such a furnace chamber is generally packed with 50,000 carbons or more, according to the diameter. On this large heap of carbon the flames are allowed to act on all sides, first gently and then in full blast. The operation of packing, carbonising, leaving to cool, and then taking the carbons out takes about five or six days. In cooling down all the heat contained in the large pile is lost, as it goes out through the flue. When the carbons are taken out it is generally found that a *very large* percentage of them are crooked—that is, have warped. The author has seen heaps which have had about 80 per cent. of warped carbons. Warped carbons in general mean loss of labour and fuel, which means money.

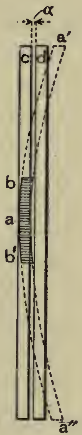


FIG. 20.—Diagram showing how Carbons can warp.

The defects of this system are, thus, the following:—(1) A carbon of a small length has relatively far more play to warp when in a bundle which is not in a retort and not packed tightly with carbon dust. In Fig. 20, for example, suppose the heavy shaded part *b′ a b* to represent a small length of carbon that has warped, while the heavy lines show two carbons of greater length *c* and *d*. It will be seen that, on the whole the warp is not much, and may be only a millimetre or two, yet such carbons are of no use in arc lamps, as they would soon fall over on the sides and short-circuit the lamp. If we suppose that this short carbon were a long one and had full play while in the furnace—that is nothing to resist the warping—it would no doubt warp, as shown by the extension in dotted lines *a′ a″*. But when using long carbon rods, and packing them tightly in retorts, the carbons cannot have such play, and so cannot warp as the dotted lines show. The space between the long carbons *c* and *d*, when in the retort, and after having shrunk is, let us say, a. If, then, the carbon c had an inclination to warp, it could not warp or bend more than the space a allows, and would thus, on the whole, be a straighter carbon proportionately than the small carbon b' a b, if warped or bent through the same space a. In other words the small carbon, using the same space that results from shrinkage, can bend through an arc of very small radius compared with the radius of the arc of the long carbon. Practice has verified this, and the number of crooked carbons obtained in the retort method is very small; if care is taken in packing it may be as low as 1 per cent. It is thus in the retort method that a great saving comes as against the older system.

(2) The furnace system has a very great influence as regards the quality and warping of the carbons. In carbonising carbons it is necessary to heat them very gently at first. The temperature should not be more than 140°C. at first, and it should then rise by small steps until the greatest heat is obtained. This cannot be done in the old system of furnace where there is only one chamber for each furnace, and where the regulation depends upon the attendant or furnace man. You can instruct him to start the furnace with a small heat for 30 or 40 hours and then increase gradually, but it is easily imagined what it is to depend upon a man in such cases, especially in the night time, when he is alone in the factory and feels like taking a nap. He will pile coal into the furnace to last for a couple of hours and retire. Then, again, where there is such a large mass of carbon in one heap, covered up well with dust and slabs, it is very difficult to heat up such a mass slowly without taking a *very long time* in doing so, considering the low coefficients of conductivity of the chamotte slabs and the carbon mass, and also the distance of the inner carbons from the source of heat. Thus, while the outer bundles of carbons may be warm or hot the inner ones may be cold, and as the heat increases there will be a sudden rush of heat that will warp all the inner carbons. In the modern system of carbonising furnaces this cannot happen, as an attendant if negligent can under no condition produce such a result, for the furnace consists generally of about 32 small chambers, and only one chamber at a time receives the heat, which then circulates through half the other chambers. It

will thus be seen that each successive chamber from the one in which the flames play, receive gradually less heat until at the end chamber the temperature of the gases is only about 140°C. to 150°C., after which the gases go into the chimney.

(3) The great saving of fuel in the modern furnace system as compared with the old one is apparent, for in the old system the carbons being all heaped up in one pile, the fire is started slowly and allowed to play against the carbon mass, after which it goes directly into the flue to the chimney. In the new system this heat, instead of going directly into the flue circulates through about 16 to 18 chambers and dissipates itself in warming up the retorts in those chambers, while the cold air that is necessary for combustion goes through the retorts in the other half of the chambers, which have been already carbonised and are hot, and thus the air takes the heat away from these chambers and arrives hot at the chamber that is in action. In the old furnace system, with a single chamber, the carbons, after being carbonised, are allowed to cool by letting the air pass through into the flue. This saving of heat is considerable in the new furnace, and means money to those who have adopted the system, while the temperature that can be obtained in the new system is much higher and more constant than that of the old system.

These are the reasons why the system of carbonising has been changed, and why better carbons are made nowadays than a few years since. Of course it is very fascinating to cut and point a large number of carbons per day when in the soft state, but all these advantages do not balance the results obtained with the new system.

I have repeatedly used the expressions "the new system" and "modern furnace"; but actually these are not new, and furnaces built as above described were first designed years ago by George Mendheim, who built them for the pottery industries and the like. Of late years they have been adopted by many of the carbon manufacturers, who recognised their advantages; and the author uses the expression "new" because there are many factories that have not got them, while some makers do not seem aware of their existence.

There is, however, another great commercial advantage in cutting down the carbons after they are baked or carbonised, instead of having them cut when soft, and that is that a manufacturer can keep a stock of carbons always on hand, and cut them down to their proper length as ordered. It would require a tremendous stock of carbons if they were already cut to the sizes used in practice, as there are about 70 different sizes. The sizes used nowadays in practice vary from 8mm. to 22mm. in diameter, and from 150mm. to 400mm. in length. It will thus be seen that, instead of keeping about 70 sizes on hand, it is only necessary to keep about 25 kinds. Formerly in the good old days, carbon purchasers gave their orders six months in advance, but now when an order comes in it is expected to be fulfilled immediately, or as soon as possible, and if you cannot promptly execute the order, the order goes to a competitor. To cut and point the carbons does not take long that every large manufacturer keeps a good stock on hand in order to be able to execute rapidly any order coming in. Some years ago there were only about three or four firms in Europe making carbons, while at present there are some 15 or more, and the number keeps on increasing as the demand for carbons is getting larger every year, while new articles also come daily into use, such as electrodes for chemical and smelting purposes, carbon brushes, &c. It is really surprising to see the number of new arc lamps installed yearly, and the number of electrochemical and smelting works that bob up in all countries, which means that there will be a greater demand for carbon articles. In fact some of the smelting works, as, for example, the Aluminium-Industrie Neuhausen, in Switzerland, make their own electrodes now, having installed a small carbon factory in connection with their works, and no doubt many others will follow, making their electrodes cheaper than they can buy them, as frequently one of the principal questions that decides whether such an electrolytic or smelting works will pay is the cost of the electrodes.

Sorting.—We will now proceed with actual carbon manufacturing again. It has already been explained how carbons are packed and placed in the furnace, which takes about five or six days. After they are baked and cooled down they are taken out of the retorts without any difficulty, as the heat has shrunk them a little, and they are not so tightly packed as when first put in the furnace. They are then sorted—that is, the crooked ones, if any, are separated from the rest, and if care has been taken it will be found that the percentage of crooked carbons is very small.

Formerly some manufacturers picked the crooked carbons out by letting the rods roll down an inclined plane. Straight carbons when rolling down an incline will roll evenly and not deviate from their course, while a crooked or warped carbon will go down slantingly or in a zig-zag fashion. Another method, and a very good one, was to pass the carbons through tubes the bore of which was but a little larger than the diameter of the carbons. If a carbon was crooked it could not pass through the tube and was laid aside. A modification of this principle is shown in Fig. 21, which shows in cross-section a machine that will assort carbons very much faster than by hand. A is a cylinder made of hard wood, and has a length which is about the same as the carbons being sorted. Upon the periphery of this cylinder, and parallel to its axis, square grooves *b b′ b″ b‴* are milled, as shown in the figure. The height and width of these grooves are just about a shade larger than the diameter of the carbons that are being assorted. This cylinder revolves about 30 or 40 revolutions. B is a fixed guard that is only a few centimetres in height, and has the same length as the cylinder. C and D are also guards, while E is an inclined platform on which the carbons are placed that are being sorted. It will be seen that the carbons, *a*, roll down and if straight fall into the grooves *b b′ b″ b‴*, and as the cylinder A revolves in the direction of the arrow the carbons are taken as far as the position of *b‴* shown in the figure (as they are prevented from falling out sooner by the guard C), from which they then fall on the receiver D, where

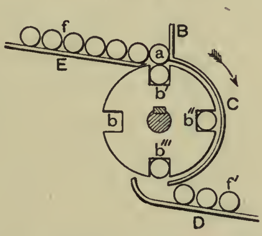


FIG. 21.—Diagram of Assorting Machine.

they roll down and are collected. If a crooked carbon gets as far as *a* it cannot go farther as the guard B prevents it, while the cylinder, which is driven simply by a loose cord, slips, or rather stops. The crooked carbon is taken away and the machine begins to work again as it is freed, For carbons of different diameter cylinders with different-sized grooves are used; in fact, each diameter has its own cylinder, which can be easily placed in the frame of the machine, or taken away. As they are simple cylinders of hard wood, having at their ends circular iron plates through which the shaft is put and keyed, they are not expensive, while two boys attending such a machine can assort about 70,000 to 80,000 carbons a day, one boy placing the carbons on the platform E, while the other keeps an eye on *a*, and extracts the crooked carbons. The author has also seen some machines working on the principle that a straight carbon only can pass between two cylindrical rollers, their distance apart being adjustable according to the diameter of the carbon that is being assorted. The crooked carbons when passing through the rollers get smashed and broken up. This is, however, not an economical method, as there are generally some parts in the length of a crooked carbon that can be used. The carbon makers generally cut out the bent and warped portions of the rod, and use the other parts for making carbons of small lengths. It is thus folly to have all the crooked carbons smashed without first inspecting them to see if any portions of their length can be used. Of course, broken carbons, &c., have to be ground up again, and it is, therefore, advisable to train the workmen in order to have as little breakage as possible, as this represents loss of labour and fuel. After the carbons have been sorted they are placed in the stock room in racks, which are divided into compartments, so that not too many carbons are piled upon each other, as they are heavy, and the lower layers may get bruised or broken.

Cutting.—If there are orders on hand for certain carbons, that particular size is taken to the cutting department, where they are cut down to the lengths the order calls for. Fig. 22 represents a cutting machine, which consists simply of a circular steel blade that revolves at about 1,000 revolutions per minute. The machine is supplied with a fixed and loose pulley, while the arm to which the cutting blade is attached is held up by means of a spring in connection with a lever that is operated by the foot. When cutting a carbon the lever is pressed, bringing down the blade on to the carbon, which rests in or between two circular rollers, as shown in the figure. On the table of the machine there is a slider, which, when set, serves to measure the carbons off in equal lengths. These machines have generally the following size: table surface about 1,000mm. by 800mm., diameter of fixed and loose pulleys 240mm., width 70mm., horse-power required about 0·25, and weight of the machine about 130 kilos.

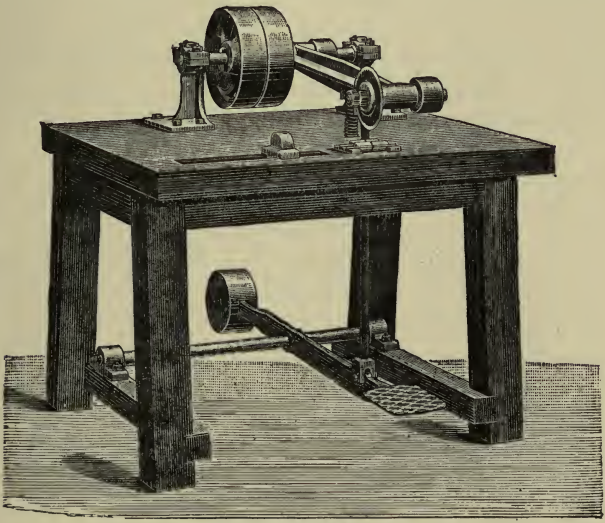


Fig. 22.—Carbon Cutting Machine.

The author is of opinion that this machine can be combined so as to do the sorting at the same time, and thus do away with the machine shown in Fig. 21. Such a combination is shown diagrammatically in Fig. 23. A represents the circular blade, operated in the same manner as has been explained in reference to the machine shown in Fig. 22. In fact, the only difference in the machine is that on each side of the rollers upon which the carbons rest there are two tubes, B B, as shown, which are held in position by means of the screws and nuts that pass through the table, this affording an easy way of replacing other tubes when carbons of a different diameter are taken. The slider D is so constructed that it can be thrown over when the carbon is cut, in order to take the carbon out. It is evident that when the carbons are straight they can pass through the tubes, which have an internal diameter a shade larger than the carbons, whereas a crooked one cannot pass, and can be broken at the point where it is bent, while the remaining part can be used according to the length of its straight portion. Such a combination would no doubt be an advantage, as it would do away with the special sorting machine; although the cutting would not proceed as fast as before, the difference would not be very great, and we should have one less handling.

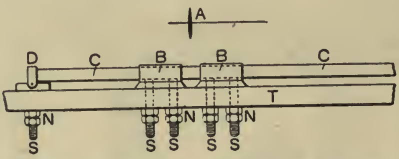


FIG. 23.—Assorting and Cutting Machine.

Grinding.—After the carbons are cut, their ends are ground off on a simple emery wheel, which process is very efficient, the work being done by boys. In connection with this wheel there ought to be an exhauster to take away the carbon dust, which is prejudicial to health. There are some who hold that a carbon works is the best place for those afflicted with consumption, and this may be due to the fact that the infusoria of the disease object to the dust which settles in the lungs. The author has, however, heard of a labourer in a carbon factory who was dissected after he had died, and whose lungs were found to be one hard black mass.

There is a grinding machine on the market now, made by Pemsel, that is said to work automatically and to grind the ends off from 20,000 to 30,000 carbons per day. Fig. 24 represents such a machine. The carbons are piled into a box, from which they are taken automatically by two revolving discs, with notches, which bring the carbons between two grinding wheels that grind their ends off evenly. They are then transported to an inclined table from which they are collected. As the author has not had any experience with these machines he cannot vouch for their efficiency, and the reader must, therefore, take his remarks with this reservation. The machine, on the whole, is expensive, costing about £110, but if it works well and does its work continuously without getting out of order it may be an advantage to have it in a carbon factory.

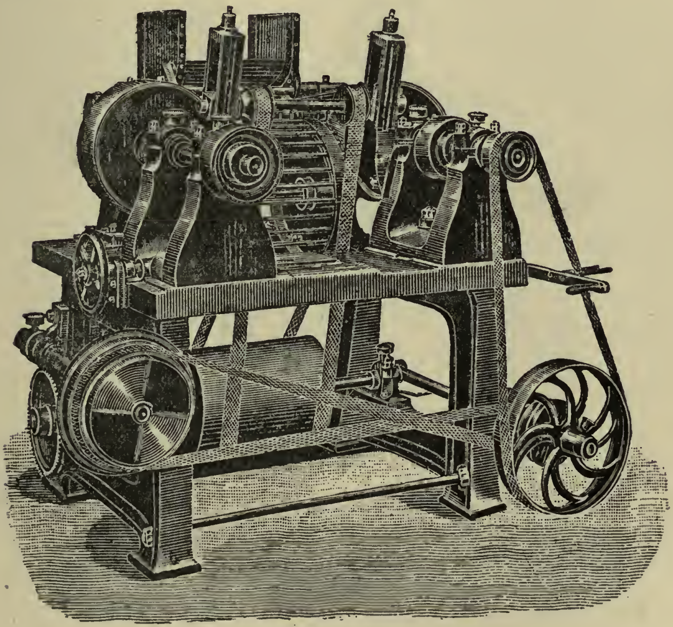


Fig. 24.—Pemsel's Automatic Grinding Machine.

Pointing.—After having their ends ground off the carbons are taken to the pointing department. The pointing machine is shown in Fig. 25. It consists of two emery wheels, well protected, so that in case of accident nothing can happen to the operator who points the carbons. Connected with the machine should also be an exhauster to draw off the dust. From 3,000 to 4,000 carbons can be pointed on an emery wheel per day, depending on the diameter of the carbons being pointed. The following are the dimensions of such a machine :—Diameter of emery wheels 320mm., and width from 30mm. to 50mm. ; height of machine up to the centre of the shaft 1,000mm., surface of table 1,600mm. by 800mm., diameter of pulley 100mm., width 60mm. ; revolutions 1,200 per minute, horse-power required about one-half, weight about 310 kilos.

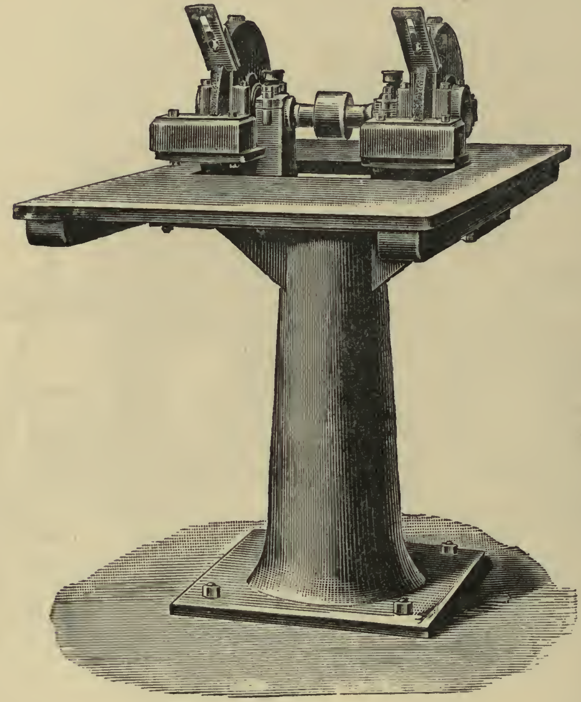


FIG. 25.—Braun's Pointing Machine.

The author may here state that many manufacturers point their carbons too much—that is to say, the angle that the cone of the point makes is smaller than is necessary, being usually less than 45deg., whereas a point having an angle of about 120degs. is all that is necessary, and the arc will strike as well with it, while time and labour are saved in the operation of pointing.

There is also an automatic pointing machine made by Pemsel, which is said to point between 20,000 and 30,000 carbons per day. Fig. 26 represents this machine. Here also, as in Fig. 24, the carbons are placed in a box from which they are automatically taken out and pointed on a grinding drum, from which they are then taken to a receiving box. Concerning the efficiency, the author can only reiterate what he has already stated in reference to the machine shown in Fig. 24. To him the machines seem complicated, and have too much gearing or belting that may get out of order, especially in a carbon factory where carbon dust is always flying about, getting into the bearings and delicate parts of a machine and grinding nearly like diamonds, soon putting things out of order. However, one cannot condemn a machine before seeing it in practical work, and if the machine will stand

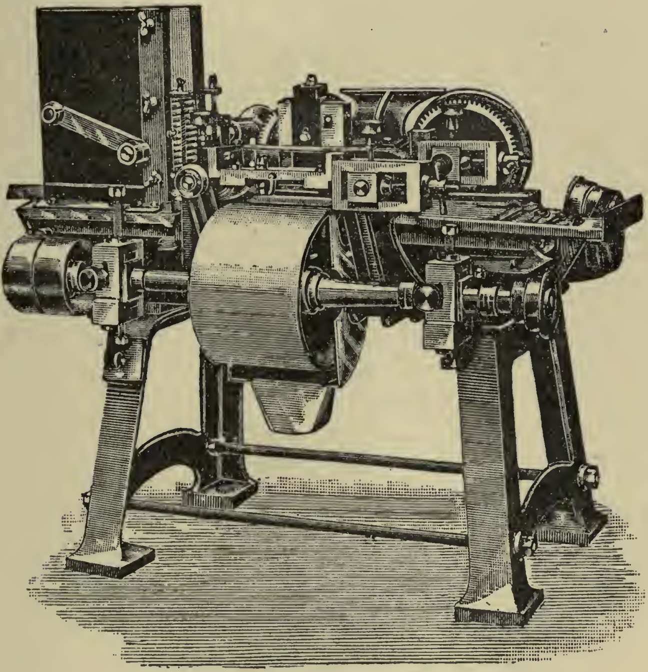


Fig. 26.—Pemsel's Automatic Pointing Machine.

the test of a year's work in a carbon factory continuously, the author will not hesitate to recommend it. The solid carbons after being pointed are ready for packing or are stored in the store-room.

Coring.—The cored carbons are taken to the coring department, where the work can be performed by girls. There was formerly plenty of talk about the salts and chemicals that the European manufacturers used in connection with the core. It was said that they alone had the secret, and that they would not divulge it. This was, however, all a farce, intended simply to frighten away those who were desirous, perhaps, of starting a factory of their own. Every manufacturer in those days looked with suspicion upon any one who would venture to question them on carbons, thinking they wanted to take away a part of the fat

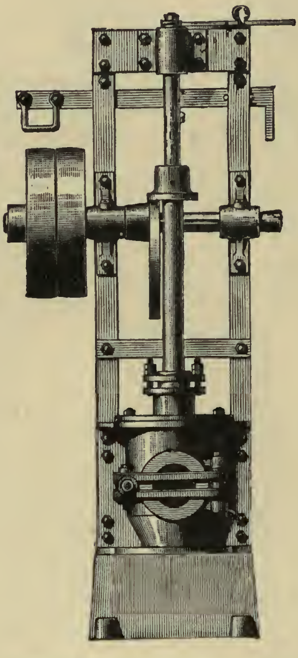


Fig. 27.—Braun's Small Crusher for Coring Mixture.

profits they were making. The fact is, however, that the only chemical that enters into the composition of the core is "Kaliwasserglas"—that is, water-glass made from potassic carbonate, and not from sodic carbonate, as the water-glass made from sodic carbonate, when used in the core, gives a sort of yellow tinge to the flame of the arc, which is not desirable, while that manufactured from potassic carbonate gives more of a white colour to the arc. One Austrian firm buy their "Kaliwasserglas" in Sennewitz, and pay about £1. 5s. per 100 kilos for it. It can, however, be bought from any druggist, care being taken that potassic water-glass is actually received; in fact, it can be easily detected if the sodic water-glass has been supplied or is mixed with the other by simply taking a piece of platinum wire, dipping it into the water-glass received, and inserting into the flame of a spirit lamp. If sodium is present it will show by giving a yellow flame, and the water-glass should be rejected. Water-glass has been found to be the best material by the aid of which the powdered carbon that is mixed with it can be squirted into the core. It acts somewhat like a lubricator, while it lengthens the arc and renders it silent, which fact was first observed by Carré. Of course, baking has something to do with it, yet it will be found that different kinds of water-glass will give different results, and the best way is to order samples from a number of druggists, and take that which gives the best results. Sometimes carbons are desired that will not draw too long an arc, while at other times carbons are wanted to work at a very low pressure (for instance, in alternating lamps), and the material must be selected according to the object it is intended for.

The coring mixture is made of well-calcinated or carbonised lampblack, sometimes ground carbons that were broken, &c., mixed with the water-glass. The well-carbonised matter used for coring is usually broken and crushed in small stamping mills made especially for the purpose, and shown in Figs. 27 and 28. Fig. 27 is a machine generally used in small factories, having only one upright stamper, while Fig. 28 is one having four stampers, and is used in larger works. The chamber in which the material is crushed into a fine powder is closed or boxed up so as to prevent the dust from flying out, and can be

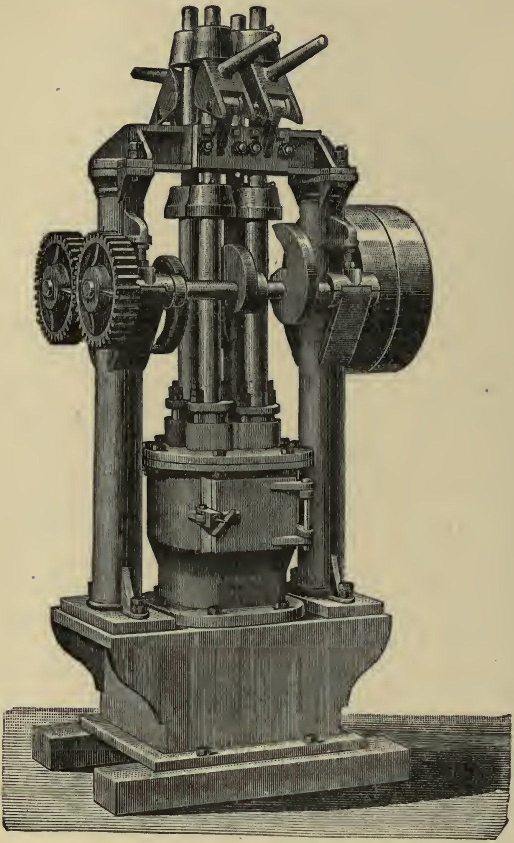


FIG. 28.—Braun's Large Crusher for Coring Mixture.

easily taken out when required at the doors shown in the figures. These machines have the following dimensions:—

——	Small stamper.	Large stamper.
Height with stamper up	2,100mm.	2,150mm.
Length with pulleys	900 „	1,000 „
Width	700 „	700 „
Diameter of fixed and loose pulleys	440 „	500 „
Width „ „ „	85 „	100 „
Revolutions per minute	45-50	75-80
H.P. required	½	1
Weight of complete machine	490kg.	1,120kg.

The material when crushed into powder is passed through a silk gauze, the carbon flour being taken and mixed with the water-glass, and the mixture then well worked up in a machine, shown in Figs. 29 and 30. This machine is similar in principle to that shown in Figs. 3 and 4, and consists of a closed chamber in which are oval runners, attached by means of an arm to the vertical shaft, as seen in the figures. This shaft receives its power through a bevel gear, as shown. The machine is about 900mm. high, having a length with pulleys of about 1,200mm., width 800mm. The diameter and width of the fixed and loose pulleys are 560mm. by 120mm., making about 50 revolutions per minute. About one horse-power is required. The complete machine weighs about 780 kilos.

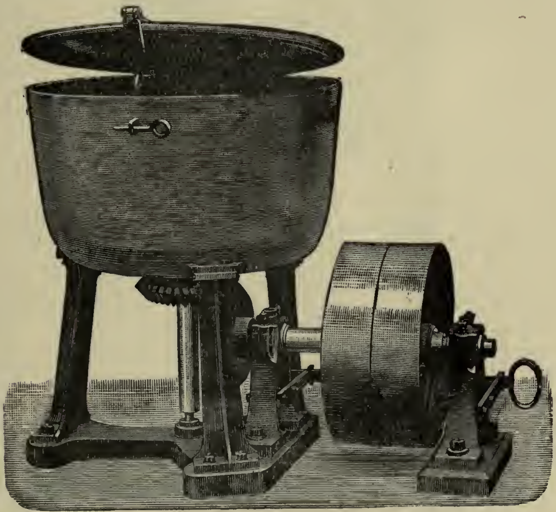


Fig. 29.—Braun's Oval Crushing Mill for Coring Mixture.

Experience will soon show how much water-glass is to be taken to a certain quantity of carbon flour, for when there is too much water-glass the paste will be too thin, and thus the cores of the carbons will not be homogeneous; the core will fall out as the water-glass is dried, and the arc will sputter. When too little water-glass is taken the paste or coring mixture will offer too much resistance in its passage through the core, and may clog up mid-way in the core. The consistency of the coring paste should be so that it does not offer undue resistance when coring.

Fig. 31 shows the coring press generally used, which consists of a cylinder sliding in a groove at the base. To one side of this, near the base, a nozzle is attached. Mouthpieces fitting into the core of the carbons can be screwed into the nozzle. The piston in the cylinder is worked by means of the screw which is driven by the hand wheel seen in the figure; when this is turned it drives or forces the coring mixture out at the mouthpiece. When the cylinder of the coring press is filled with the coring mixture care should be taken that no air bubbles are left, which might get into the core, making it porous, and causing the arc to splutter when the carbon is consumed at that place. The cylinder being filled, it is slid back into its right position. The coring

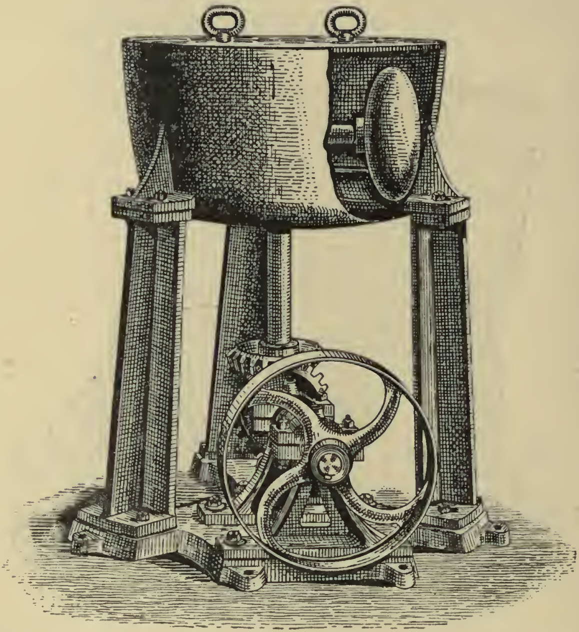


Fig. 30.—Pemsel's Oval Crushing Mill for Coring Mixture.

of the carbons can now commence. The mouthpiece at the nozzle of the coring press is inserted into the core of the carbon, which is held in one hand while with the other the wheel is turned down, which forces the coring mixture into the core of the carbon. The carbon is slowly drawn out, so that some of the coring mixture will fill that part of the core that was taken up by the mouthpiece.

With a little practice the person operating the coring press will soon acquire a dexterity that will enable him to core 5,000 to 6,000 carbons per day. It will sometimes be found that the carbons break when subjected to the sudden pressure of the mixture. Carbons of large diameter are more easily cored than those of small diameter, the latter having smaller cores, which naturally offer more resistance than larger ones.

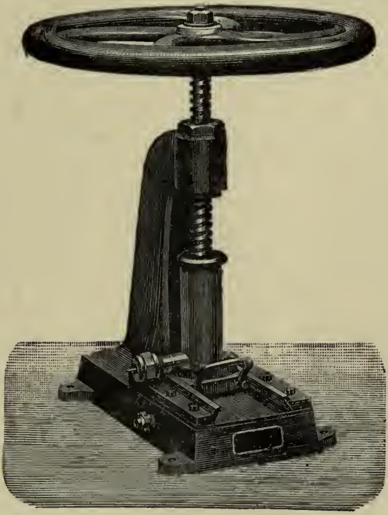


Fig. 31.—Coring Press.

Too much stress cannot be laid upon the necessity of good coring, as the steady working of the arc lamp depends to a great extent upon the manner in which the carbon has been cored. No doubt many electric light engineers have had experience with carbons that were cored badly, and did not know at first why the lamps sputtered, why sometimes a lamp was short-circuited (by a piece of core falling out), or why they chattered, until at last the cause of all the trouble was found to be due to bad coring. When the coring paste is too thin it will be found that the core is often loose, that there are many air-spaces as the water-glass gets dried up or contracts in volume, and there remains the carbon of the coring mixture as a core in a spongy state, to the annoyance and inconvenience of the engineer. Many manufacturers have lately designed the cross-sections of their core otherwise than a plain circle in order to get more surface on to which the core can hold and stick without falling out. If care is taken in the making there is no doubt that all these evils can be averted, but some workmen try to core quicker than is advisable.

Hints to Electric Light Engineers.—There is one fact which has no doubt been often noticed by electric light engineers, and that is the unblushing simplicity that some manufacturers of carbons will put on when complaints are made about the quality of their carbons or cores. They will tell you that it is impossible that the fault is in their carbons, that they use the best material and core with the utmost attention, and the like. They will then "guy" the party complaining, asking him if he is sure that his lamp is regulated, or if he has enough resistance in his lamp circuit, or if the volts that operate his lamps are not too high or too low. They will even go so far as to send one of their men to look at the lamps and instruct him to find out what is the matter, although, if they understand their business, they must know where the fault is. The man will regulate the lamp every five minutes, will do this or that, and by so nursing the lamp and carbon things will appear as if the fault really did lie somewhere else. Give a fainting man a cordial it will revive him, so also in this case, but when the lamps are out of the testing room the old troubles will commence. Then, again, in testing samples it has been the author's experience that if the samples are not taken from stock, the tests are of no value; for carbons, made expressly for samples by the old system, turn out generally very different from those that are made to fill an order. Samples often appear very excellent, and then when the order is filled the carbons are rejected. The author gives the following explanations how such a thing can happen, when using the old system of baking carbons :—

The author has seen samples made from the raw material generally used, which were packed and put into a retort that was placed in the common flue into which all the hot gases coming from the individual furnaces egress. Here they were well carbonised, and the tests made with them were very satisfactory in all respects. Now when the carbons were made, which were to be of the same quality as the samples that were submitted, it was found that their quality was not the same, although the raw material used was the same as that used for making the samples. The only difference was that the samples were baked in a retort that was placed in the flue, while the other carbons were baked in the chamber of the furnace. A little reasoning would have shown this particular manufacturer that the carbons are carbonised much better in the flue than in the chamber of the furnace, and that it was high time to discard such a system of furnaces where carbons were baked better in the flue than in the chamber. This instance will show how much heat is wasted in such old carbonising furnaces, and how preferable the new system is where the furnace has many chambers that take up the heat which is lost in the flue of the old system, and where retorts are used around which the heat can act and get at the carbons, thus heating them evenly and carbonising them well.

In coring it is well to press the tip of the finger on the pointed end of the carbon that is being cored after the air has been forced out, in order to get the coring mass in the carbon as compact as possible. Care should be taken also that the coring mixture is not smeared all over the tips of the carbons, as this produces an enlarged flame when they are in the lamps. Some manufacturers clean the carbons after the core has been dried by running them between two revolving wheels, on the rim of which soft wire brushes are attached. The author is of opinion that it is much better to always take the coring paste direct out of the machine (shown in Fig. 29) when it is needed (as it is always well mixed) than to take it out of a reservoir, where some manufacturers put it after it has passed the machine, and where it may perhaps settle, and thus not be of an even consistency.

Some manufacturers use a kind of semi-automatic machine for coring. This machine consists of a large cylinder that may contain about three litres of coring paste. The piston of this cylinder is weighted down by means of iron weights, which force the paste out at the mouthpiece. In the nozzle of the cylinder there is a sort of sliding valve which is worked forward and backward by means of gear-wheels and eccentrics. When the valve is pushed forward it is opened and the coring mixture can pass, when it is taken backward the valve is shut. In connection with the gear-wheels there is actuated also a sort of holder, into which a carbon is laid; the latter is then pushed forward into the mouth of the nozzle, where it is cored, then pushed backward again, and taken up by two revolving arms and thrown on to a table. The arms, holder and valve are all worked by gear-wheels and eccentrics as mentioned above, and so adjusted that they act at the proper time. It will be seen that such a machine works on a periodical principle, allowing a certain time for each carbon to get cored—or not. Care must be taken in coring, and generally it cannot be well done if a certain prescribed time is allotted to each carbon, as one carbon may, for some reason or other, want more or less time. For this reason it is preferable to use the hand press (shown in Fig. 24). Then, again, with the hand press a better—that is, a thicker—paste can be used, which gives a compacter core. An automatic coring machine can core about 20,000 a day, and for cheap carbons may answer the purpose.

Drying.—After the carbons have been cored they are placed in trays or pans of sheet iron, which are pushed into the drying oven in order to get the water-glass of the coring mixture or paste dry. The drying oven may consist simply of a large chamber, into which the trays or pans can be placed above one another, and it should have a temperature of about 100 to 120°C. There must be a little opening at the top somewhere, in order to let out any moisture that may have been driven out of the carbons. Heat can be obtained from a small fire built underneath the chamber, which is, of course, made of sheet iron. The best way is to have two such drying chambers, side by side, with the fire between them. When one chamber is full it can be kept closed while the other is being filled. Heating by gas is not as desirable as with coal. If properly constructed, there is no valid reason why gas heat should not work equally well.

Cleaning and Packing.—After the core has been dried the carbons are passed through the cleaning wheels smeared over with coring paste, as already described. They are then taken to the packing room and put up in bundles of 100, 50 or 25, according to their diameter, tied well with twine and wrapped in heavy paper. It is also well to label each package, to show at a glance the quality, kind and number of carbons contained, as otherwise there is often confusion and delay. The carbons are then either placed in the store room or sent to the shipping department. Every carbon factory should have a circular saw and a box maker, as buying packing cases is much too expensive. When the carbons are being packed in boxes or cases for shipment, the packages should be well cushioned with wood-flock, so as to prevent breakage during transportation. The cases should be packed with 1,000 carbons only, as with that quantity they can be handled easily and are so preferred by agents, who need not then repack them, as they are generally sold in thousands. When shipping carbons for a long sea voyage, as to the Far East, the cases should be lined with zinc, or at least with wax-cloth, in order to prevent moisture from getting in.

Each case should be clearly stencilled, stating the quality of the carbons contained, whether for direct or alternating current, cored or solid, the diameter, length and quantity. This will save much trouble to Custom House officials, and, in fact, make it easier wherever the case or cases may go. The author has experienced a deal of trouble on account of cases not being properly marked, with cases containing cored and solid carbons mixed or different sized carbons, and with cases containing 1,500 or 2,200 pieces. Carbons should, as already stated, only be packed in 1,000 lots and of one kind, as otherwise handling becomes difficult and is expensive and troublesome for the agents.

Electrodes.—It is hardly necessary to write much upon the subject of electrodes, &c., as these can be considered as solid carbons, having only a different cross-section. They are usually made from petroleum coke or gas graphite.* The raw material is worked in the same manner as that for arc lamp carbons, and they are squirted by the hydraulic presses as has been explained. Should the cross-section of an electrode be irregular it must then be pressed by means of a plunger hydraulic press. For electrodes of large size the hydraulic press No. 5 should be used, while for electrodes having a cross-section of about 50mm. × 150mm. or under press No. 3 can be used. In making carbon brushes it is best to use petroleum coke to which about 10 to 15 per cent. plumbago is added, which acts as a lubricant. The brushes, or the material, is squirted out of the press in long slabs, the cross-section of which is the same as the brush should have. The slabs are then packed and baked in the furnace, after which they are cut down to their proper length. Some manufacturers cut the slabs while in the soft state into the proper lengths, and then pack them in chamotte boxes and bake them. If the brushes have an irregular cross-section they must be pressed by means of a plunger press, as already stated. Large-size electrodes are generally sold per 100 kilogrammes, the price varying from £1. 10s. to £2. 10s. Electrodes for special purposes are, of course, more expensive. Electrodes that are used in electro-chemical works demand greater attention than those for smelting works, as they should not contain any cracks into which the electrolytic fluid can be absorbed, as it may result in the generation of gas or heat, which might rupture or break the electrode. High pressure in squirting them and high temperature in carbonising them is absolutely necessary in order to get a homogeneous and hard electrode. The author made experiments some time ago by flashing some electrodes in hydrocarbon gases and fluids, and found that he could obtain a pretty hard and even surface without any cracks when looking at the product through the microscope; in fact, such a surface seemed an ideal one for electrolytic work.

---

* From the tests recently made by Stanger and Blount upon various samples of electrodes, it was found that those made from gas retort carbon were the most satisfactory in all respects (see *The Electrician*, May 28, 1897).

CHAPTER V.

HINTS TO CARBON MANUFACTURERS AND ELECTRIC LIGHT ENGINEERS.

In running a carbon works, a system should be initiated, whereby each department has printed forms on which is noted an account of the daily work done. Such statements afford an insight into the cost and expenses of each department which every owner should have, although this is not generally done. A good telegraphic code will be found convenient in the office of every carbon factory which exports into foreign countries. The blank spaces to be found at the end of the book should be filled with paragraphs that are constantly being used in the trade, and experience will soon show what sentences are most useful.

The sizes and dimensions of carbons mostly met with in Europe are given in the following Table, which shows also the current, voltage used, and life of the various-sized carbons. The Table is taken from the list of one of the best-known firms of Europe, whose carbons are generally taken as a standard:—

For Direct Current, soft quality.

——	1	2	3	4	5	6	7	8
Volts used at lamp	36	37	38	40	41	43	44	45
Amperes used in lamp	3	4	6	9	12	15	20	35
Diameter of cored carbon in mm.	11	13	16	18	20	20	22	25
Diameter of solid carbon in mm.	7	8	10	12	13	13	14	18
Length and life of carbons—								hrs.
200mm.	8½	10	10	10	10	10	10	10
250mm.	11	13	13	13	13	13	13	13
290mm.	13½	16	16	16	16	16	16	16
325mm.	15	18	18	18	18	18	18	18

The lengths of the positive (uppers) are the same as the negative (lowers).

When a harder quality is used, solids are generally taken having 1mm. less diameter than those given in the above Table.

Carbons for Alternating Current.

—	1	2	3	4	5	6	7	8
Volts used at lamp	26	26	26	26	26	27	28	30
Amperes used in lamp	3	4	6	9	12	15	20	35
Diameter of cored carbons, upper and lower in mm.	7	8	9	10	12	14	16	20
Length and life of carbons—								hrs.
200mm	7	7	7	7	7	9	9	9
250mm	9	9	9	9	9	12	12	12
325mm	12½	12½	12½	12½	12½	16	16	16

On the Continent a cored carbon is generally used having a larger diameter than the solid one in direct-current lamps, while the length of both upper and lower are the same, and burn at about the same rate per hour. In England and America it is generally the custom to use carbons of the same diameter in a lamp, while the ratio of the lengths of the upper and lower are about as 12 to 7 respectively. However, the Continental sizes and proportions are being slowly introduced in both countries. The English and American sizes are generally the following:—

	For direct-current lamps.					For alternating-cur. lamps.	
Diam.	7/16 in. × 12in.	cored, and	....	7in.	solid.	Diam. 7/16 in. × 7 in.	length.
„	½ in. × 12in.	„ „	....	7in.	„	„ 7/16 in. × 9½in.	„
„	9/16 in. × 12in.	„ „	....	7in.	„	„ ½ in. × 7½in.	„
„	⅝ in. × 12in.	„ „	....	7in.	„	„ ½ in. × 9½in.	„
„	9/16 in. × 10in.	„ „		7/16 in. × 7½in.	„	„ 19/32 in. × 6½in.	„
„	½ in. × 10in.	„ „		⅜ in. × 7½in.	„	„ 19/32 in. × 7½in.	„
„	⅝ in. × 10in.	„ „		½ in. × 7½in.	„	„ 19/32 in. × 9½in.	„
„	½ in. × 12in.	„ „		⅜ in. × 9½in.	„	„ ⅝ in. × 7½in.	„
„	9/16 in. × 12in.	„ „		7/16 in. × 9½in.	„	„ ⅝ in. × 9½in.	„

The following Table, giving the sizes in English measure and their equivalent value in the metric system, will be of use in calculating one into the other, and will save time to the person making out invoices for foreign countries:—

3/16 in.	equals	4·76	mm.	⅝ in.	equals	15·87	mm.	8in.	equals	203·19	mm.
¼ in.	„	6·34	„	¾ in.	„	19·05	„	8½in.	„	215·89	„
5/16 in.	„	7·93	„	1 in.	„	25·40	„	9in.	„	228·59	„
⅜ in.	„	9·52	„	1lb.	„	0·453	kilos.	9½in.	„	241·29	„
7/16 in.	„	11·11	„	1 kilos	„	2·20lb.		10in.	„	254·00	„
½ in.	„	12·70	„	6in.	„	152·39	mm.	12in.	„	304·79	„
17/32 in.	„	13·49	„	6½in.	„	165·09	„	16in.	„	406·39	„
9/16 in.	„	14·28	„	7in.	„	177·79	„	1,000ft.	„	304·79	mets
19/32 in.	„	15·08	„	7½in.	„	190·49	„	1,000mets	„	3,280·89ft.	

Millimetres multiplied by 0·03937 give inches.
Inches „ „ 25·40 „ millimetres,

Another useful little Table to carbon makers is the following, showing at a glance how many feet or metres there are contained in 1,000 pieces of carbons of various lengths:—

1,000 pieces	6	inches	long, equal	500	feet, or	152·3	metres.
„	6½	„	„	541·6	„	165·3	„
„	7	„	„	583·3	„	177·7	„
„	7½	„	„	625·0	„	190·5	„
„	8	„	„	666·6	„	203·0	„
„	8½	„	„	708·3	„	215·8	„
„	9	„	„	750·0	„	228·6	„
„	9½	„	„	791·6	„	241·3	„
„	10	„	„	833·3	„	254·0	„
„	12	„	„	1,000·0	„	304·8	„
„	16	„	„	1,333·3	„	406·4	„

Testing Room.—Every carbon factory should have a well-equipped testing room, where all kinds of tests can be made with carbons, as these various tests will often serve as a good criterion in ascertaining the quality of a carbon. There should be direct and alternating current available, and the machines should be driven from cone counter-shafting, by means of which the speed of the dynamos can be altered: this especially in alternating-current testing, where it is often desirable to test the carbons under the same conditions as prevail in practice. By altering the speed the frequency can be changed. It may be mentioned that, as the load on the steam engine running the carbon factory often varies during the day, and sometimes occasions variations in the speed of the engine, which often causes trouble and disturbs tests, it may be advisable to run the dynamo or alternator from a small motor driven from an accumulator battery. By these means a steady speed can be obtained without using a cone counter shafting, as the motor can be regulated to any speed. If a carbon factory is near to the mains of a supply station the motor can be readily supplied with current from this source.

The testing room should be supplied with the principal arc lamps used in practice, and the circuit should contain recording volt and ampere meters. From the diagrams taken by these instruments can be seen at a glance what the quality of the carbon is, and when they contain many peaks it will show that the carbon did not burn steadily, and that the quality is nothing exceptional. The life of the carbon is also given by such instruments; they are, in fact, of great value to the carbon maker, as he can study the tests in the same way as a steam engine engineer studies his indicator diagram. There are many little points about the diagram that cannot be explained here, and which practice alone will soon bring out. The arc lamps in the testing room can be enclosed or placed in racks, on the sides of which small windows are made, filled in with either red or blue glass (sometimes red and blue together), through which the arc can be observed and studied. Underneath the arc lamps there should be tin pans to catch the dust. There should also be a photometer in the testing-room: one of the Bunsen kind will be accurate enough for practical purposes, as generally the main object is to get relative values. For this purpose an incandescent lamp of about 50 or 100-c.p. can be taken as a standard, while the light of the arc is dimmed or toned down by means of ground glass. The factor, or constant, by which the results of such a test must be multiplied, can easily be obtained by making a test with an incandescent lamp whose candle-power is known, and noting the difference when the ground glass is interposed. It is also necessary in testing carbons to know what arc they produce when supplied with a given current and volts. The simplest and prettiest method is by using a simple photographic lens, and interposing it between the arc and a screen whose position is regulated until a full inverted picture of the arc is obtained. As the picture of the arc is magnified it is only necessary to measure off the distance from the lens to the arc, and to the screen, to get at the real length of the arc, as the length of the arc is to that of the picture as the distance between the arc and the lens is to the distance between the screen and the lens. This method not only enables us to measure the length of the arc, but by observing the picture we can see if the arc is steady, and if the core works well, and in general it affords a way by which every peculiarity of the arc can be studied without tiring the eyes.

Every testing room should have also a good balance, by which the dust of the carbons can be weighed. It is also well to have graduated test tubes in order to measure the volume of dust, as some dust has a larger volume for the same weight than other kinds, depending often on the make. A set of low volt and ampere meters of the Weston pattern for measuring the resistance of carbons is very desirable, as the best way to measure the resistance is by using a few amperes and noting the voltage between the two ends of the carbon tested. In making comparative tests of carbons the following observations should be made :—

(1) Measure the diameter and lengths of the carbons. It is well to use a sliding vernier gauge in measuring the diameter, as on an ordinary gauge a difference of 0·5mm. cannot be readily detected, and this difference has some perceptible influence on the life of a carbon.

(2) Measure and compare the relative intensity of light given by the carbons, taking care that the arc and its angle to the screen of the photometer are the same in both tests.

(3) Measure and compare the rate of consumption per hour, making a 10-hour test, as tests of shorter duration are often misleading. Of course, the conditions of the tests should be the same in both cases, and the energy consumed should be the same.

(4) After the carbons have been consumed, weigh the amount of dust, and also take their volumes. A good high grade carbon should give very little dust, and one trimming generally shows hardly any. Carbons that are not baked enough give a lot of dust and disintegrate much. They have also a higher resistance than those well baked.

(5) Measure the resistance of the carbons; a good carbon has always a lower resistance than a bad one.

(6) Measure the length of the arc with a given voltage. With badly baked carbons higher voltage is generally necessary to maintain a certain length of arc than with well baked ones. Hard carbons are better adapted for maintaining a small arc than soft carbons, while soft carbons are better for a large arc, and give a good emission of light. Soft carbons and those having a fine grain are the only ones suited for good alternating work. Such carbons should also work with a low voltage. It is evident that a carbon giving a larger arc with a given voltage is more stable than one giving a small arc. The former is not expected to chatter, as it has a larger play should there be variation in pressure on the line, whereas one with a small

arc will begin to chatter the moment the pressure sinks a little.

(7) Notice the colour of the light given by the arc. A practical way is by simply holding a piece of white cardboard in front of the arc and playing it up and down around the arc. If there is any blue or yellow light given by the arc it will show on the cardboard. Another way is to put the globe (ground glass) on the lamp. Blue light is generally due to an excessive pressure at the lamp terminals of the lamps, while yellow light may be due to too low pressure, badly baked carbons or bad coring.

(8) Cut a piece of the carbon down to 100mm. and weigh it in order to get its approximate specific gravity. Taking the weight in grammes, dividing it by the cross-section (in square millimetres), and multiplying the quotient by 10 will give its specific gravity. Hard carbons have a higher specific gravity than soft ones. Also badly baked carbons vary in specific gravity.

From the above tests a carbon maker can often find the good or bad points in his make of carbons, and it will often afford a good criterion as to the qualities of a competitor's make. He will find that, when the carbons are badly carbonised, they will offer a large resistance, that, when burning, they will often crumble so that the points present a very small angle, while there will be a large quantity of dust, the light will not be good, and a good deal of hissing. Good baking or carbonising seems to be a cure for many troubles. If a competitor has a good carbon, it is of advantage to procure samples and make the tests given above, which will serve as a means of getting at the manner in which the carbons were manufactured. From the specific gravity it may often be possible to get an idea of what pressure they were squirted at when coming out of the press, as carbons squirted at a low pressure are generally less dense than those squirted at a high pressure. When carbons are squirted at a low pressure the carbon mass or mixture must contain somewhat more tar than when forced out at a high pressure. The specific gravity of electric light carbons varies from 1·11 to 1·45, and the mean may be taken as 1·23. Soft core carbons have a specific gravity from about 1·18 to 1·20, soft solids about 1·25 to 1·30, hard-cored carbons about 1·30, and hard solids about 1·33. It is evident that there should be a difference between a cored and solid carbon on account of the core, the density of which is much less than the body of the carbon.

A few words relating to the arc will not be amiss here. On the Continent the lengths of the arc in lamps are generally regulated according to the amperes consumed. For instance, in direct-current lamps an arc of

1 to 2mm. is taken for 5 to 8 amperes.
2 „ 3 „ „ 8 „ 10 „
4 „ 5 „ „ 10 „ 20 „

However, small arcs give much trouble, for when the pressure drops a little the arc begins to hiss or chatter. In practice alternating arcs are generally regulated so that their lengths are about 3mm. When an arc is too large it flames, giving a blue or violet light. In an arc there is a certain definite length at which the intensity of the light is the greatest, and if the length of the arc is increased or diminished the intensity of the light diminishes. This length of the arc, of course, depends upon the conditions at which the lamp is being worked, and whether the arc is free or enclosed. The voltage generally used in practice for direct-current lamps varies from 35 to 45 volts for arcs that are free, while nearly double the pressure is taken for enclosed arcs. The extra number of volts in the latter kind of lamps is compensated for by a smaller current, so that the watts are about the same in both cases. The voltage in an arc lamp may be divided into three parts, as the arc itself does not take the whole. The greater part of the volts are taken up at the point where the current jumps from the positive pole over to the arc, at which point it is said to encounter a back E.M.F. which it must overcome. Another portion of the volts is taken up by the arc itself, while the last portion is taken at the point where the current jumps over to the negative pole. Small particles of carbon are taken from the positive pole and carried over to the negative. Some of these carbon particles are volatilised into hot carbon vapour, while others become incandescent. The carbon vapour when in contact with the air combines and produces carbonic acid gas and carbonic oxide gas. Other particles around the circumference of the carbon are disintegrated by the heat and fall down as dust, the more so when badly carbonised.

It is also well known that the temperature of the positive point is much higher than that of the negative, and being so it is used as the upper carbon in lamps, as it emits a large amount of light. The intensity of light given by carbon varies nearly inversely as the diameter—that is to say, when using carbons of a smaller diameter a greater intensity of light is obtained than when carbons of larger diameter are used. However, there is a minimum diameter, after which the intensity decreases when smaller diameters are taken. The above facts justify the American and English practice of using carbons of smaller diameter than those generally used on the Continent, while the object of the Continental method is to obtain a pair of carbons that will last long and yet not required to be used in very long lengths, as with long lengths it is necessary to have long lamps. Another object is to have about the same rate of consumption for both carbons, whereby the arc remains fixed in position if suitable lamps be used. It is claimed for the Continental method that, by using a larger diameter for the core, there is a better crater surface that reflects and throws down the light where it is wanted as against the method of using smaller carbons of even diameters. It must also be noticed that generally the negative carbon used on the Continent is smaller than those used elsewhere, and thus does not obstruct the rays of light as much as negative carbons of larger diameter.

The alternating-current arc may be considered as a continuous series of reversals, in respect to the poles, of the actions that take place in the direct-current arc. Both carbons thus in an alternating lamp assume about the same form when burning, and are consumed at about equal rates. As a matter of fact, the upper carbon is consumed a little faster, on account of the washing produced by the upward currents of air. A noticeable fact with alternating-current arcs is that they require less volts and somewhat more amperes, as lamps exist that use from 23 volts upwards. Only high-grade soft carbons of fine grain give satisfaction in alternating lamps, while both carbons are generally taken cored. Defects in carbons show themselves more readily in alternating than in direct-current lamps, and, on the whole, alternating lamps require more attention than direct-current lamps, as they are, if I may use the expression, very fidgety.

The distribution of light in an alternating arc is more even in all directions than in a direct arc, which gives the most light from its positive pole. On this account a small enamelled reflector is generally placed over the arc in alternating lamps. The frequency of the current has also an influence on the light, as a high frequency gives a better and steadier light than a low one, for if the frequency fall below 40 per second the arc flickers. The hissing qualities of the alternating arc are also noticeable, especially when bad carbons are used—carbons that are hard or have an uneven core. There is no doubt, however, that the peculiarities of the current has a great deal to do with this noise, although good carbons will tend to smooth down matters in general. Nikola Tesla has made a great number of experiments with the alternating arc at different frequencies, and has found that when the frequency of the current was increased the tone was increased in shrillness up to a certain frequency, at which it ceased altogether, although the frequency was still increased.

Every carbon factory should have a small chemical laboratory, fitted out with reagents and the principal chemicals. There should also be a small furnace, in order to make preliminary tests when necessary, and for experimenting.

CHAPTER VI.

A NEW RAW MATERIAL.*

Having thus described and explained the process of manufacturing the modern electric light carbon, &c., the author desires to add a description of a process for manufacturing a new raw material intended to be a substitute for gas retort graphite or petroleum coke. A carbon manufacturer, who has given much time to this subject, informed the author some time ago that he expects to be able to silence all competition with this new raw material for the manufacture of electrodes and second-grade carbons. As the author is sceptical of this, he leaves to the judgment of the reader whether the following process is likely to produce a material possessing any advantage over the material at present used. The manufacturer referred to has built an elaborate and expensive plant, which is used to clean this raw material, and free it from the impurities it contains. He has also taken out patents for the process, but it remains to be seen if such patents are valid, and even then it remains to be proved that the whole can be worked so that it is a commercial and practical success. The material in question is nothing more nor less than a sort of bituminous or anthracite coal, of which large deposits are found in Bohemia, especially near Budweis ; there are also large deposits in Hungary and southern Russia, near Rostov. No doubt the same sort of coal exists in many other countries. This coal seems to belong to a middle class, that is, between

---

* This chapter was written in the early part of 1898, and the author has since been informed that the "new" material and process mentioned therein has been abandoned. These experiments, therefore, now pass over to the historical researches that have been made in connection with the development of the modern carbon.

peat or turf and the common mineral coal. As it contains large quantities of bitumen it has consequently a large percentage of carbon, also some hydrocarbons, iron oxide and silicates. It was the cheapness of this raw material that fascinated the manufacturer, as its price is something less than ordinary coal; but it is, of course, not this price only that is to be taken into consideration, it is the cost of transporation and the expense of cleaning it, together with the interest and redemption on the expensive chemical plant that must be added to the price of the material in order to find out if it will pay to manufacture the finished products. We all know what it is to get rid of iron oxide and silicates in a raw material, and the expenses incurred in such a process seem more than it is possible to expend on such an article as carbon, whose market value is so low; it would, therefore, require serious consideration before putting up a large, costly plant to work it in the first place. It is in practice found necessary, in the first place, to calcinate this raw material, in order to drive out the hydrocarbons and gases present. This is done by putting the material in long iron retorts that are placed in an inclined position in the furnace. These retorts are about four metres long, and have an elliptical cross section. The retorts are fixed in the furnace, and at the upper end there is an opening or door into which the material is thrown, and when all the gases have been driven out this is taken out at the lower end through a similar opening or door. There is, of course, a small opening in the retorts to allow the gases that have been liberated to pass out, and these gases are generally conducted into the furnace so that they can be used in heating also. The hot material as it falls out of the retort when the lower door is opened, is allowed to drop into a bin, into which the air cannot get, to avoid burning.

After this the resultant material is ground up into powder, and then put into a large vat-like receptacle that is lined with lead and closed up. In these receptacles revolving vanes work, also covered with lead, as the material is subjected to a treatment of hydrofluoric acid, to release the silicates which it still contains. The vanes in the receptacles constantly stir up this mixture in acid and water, so as to give the material a good washing. The hydrofluoric acid must be made on the premises, as it would, of course, be out of the question to buy the acid in the open market on account of the expense.

To the author the process seems much too expensive even to manufacture such an acid, considering the large plant required and the enormous depreciation of the same on account of the corrosive nature of the acid. A chemist informed the author that the hydrofluoric acid plant at the particular factory mentioned was, no doubt, the largest in Europe. This acid is usually made in small quantities in chemical works, as the demand is limited.

The plant for making the hydrofluoric acid consists of two large leaden vats, covered on the outside with iron, and resting over small furnaces. It would undoubtedly be better to heat these vats by means of steam worms as, in this way, the heat could be better regulated than with a furnace. The diameter of the vats are about 2,000mm., while the lead lining has a thickness of 10mm. Over these vats are leaden covers which fit into a groove so that they can be well smeared up with clay in order to prevent the fumes from getting out when the vats are in action. When a vat is charged, the leaden cover is lifted by means of a small hoist and one part of finely-powdered fluorspar is mixed with two or three parts of oil of vitriol. The fluorspar should be free from silica and metallic sulphides. This mixture forms a sort of transparent gelatinous mass. The cover of the vat is then lowered and firmly sealed, while a leaden pipe of about 250mm. diameter, which makes connection at the middle of the cover, leads the fumes that arise, when a gentle heat is supplied to the vat, away into a series of six or eight large Woulf leaden bottles. These leaden bottles are about 1,000mm. high. Owing to the powerfully corrosive action of the fumes or acid, only leaden or gutta-percha lined receptacles can be used, as platinum bottles would be out of the question, from being too expensive. The series of Woulf bottles is placed in a large iron reservoir which is filled with water. The fumes thus condense in these bottles, after which the acid is conveyed to a leaden resevoir, where it is ready for use, being led through leaden pipes to the receptacles containing the new raw material as mentioned above.

The properties of hydrofluoric acid are well known. It boils at about 16°C. (60°F.) and attacks with great avidity silicon and dissolves many of the metals. Its fumes are most dangerous. The chemical action of the fluor spar, or calic fluoride, with sulphuric acid is given by the equation :

$$CAF_2 + H_2SO_4 = 2HF + CASO_4.$$

Calic fluoride costs about 8s. 4d. per 100 kilos. ground up and ready for use, sulphuric acid about 6s. Hydrofluoric acid, when bought retail, costs about £2. 10s. per 100 kilos. At anything like this price it would be impossible to use such an acid for a product which, when finished, brings a low market price. By making the acid on the premises it costs £1 per 100 kilos., which is still too high for practical purposes.

The hydrofluoric acid is worked up into the receptacles containing the raw material by means of vacuum pumps, the chambers of which must be lined with gutta-percha. The receptacles in which the material is cleaned are between 2,000mm. and 3,000mm. in diameter. After the material has been well treated with a diluted solution of the acid, it is allowed to pass into another similar receptacle, where it is washed with water, and then passes into a third receptacle, where it is treated again with hydrochloric acid in order to free it from the iron it still contains. All these receptacles contain vanes, which work by means of a vertical shaft driven by a pulley. The vanes stir up the material, which, as it is mixed with water, forms a sort of slush that is easily conveyed through pipes from one vessel to another. After this treatment the raw material is passed on to a large filter press, about eight metres long, and containing, perhaps, 30 to 40 veritcal compartments. The material is here again well washed with water in this filter press so as to free it from all traces of acids, and is then allowed to settle, after which it is taken out and placed in a drying chamber, consisting of many horizontal compartments only about 100mm. high. These compartments are heated by means of a steam jacket. When the compartments are full the air-tight door is closed, and a steam vacuum pump sucks the moisture from the material, which is then finished and ready to be worked into carbons or electrodes, in the same manner as other raw material.

The author has seen carbons made from this raw material, and certifies that the light emitted was good and white. The life of the carbons was about the same as those in general use, but they gave off very much dust and had a red appearance, showing that iron was still present. The lower part of the tips had vitreous beads, indicating again that all the silica was not removed from the mixture. When these difficulties are removed the new carbons will certainly give satisfaction on account of their white light.

However, the cost of cleaning the raw material by such a process as described is, according to the author's view, far in excess of the saving in material over that of petroleum coke or gas retort graphite. The author estimates the cost of the chemical plant at the factory at from £7,000 to £8,000, on which certainly 25 per cent. must be allowed for capital, interest and depreciation, as nothing can withstand long the action of the acid used. Taking this percentage, we have a sum of nearly £2,000 a year, for which sum nearly all the petroleum coke or gas retort carbon that such a factory needs could be purchased.

This process was, so far, more of an experiment, and the author has been informed that a chemical expert is still working on the subject, while the manufacturing firm contemplates purchasing a mine situated in the Caucasus, from which the best samples of the anthracite coal referred to can be obtained.

No doubt the most logical method of producing a good and substantial raw material, especially adapted for manufacturing electrodes, &c., is that given by Mr. E. G. Acheson, who invented the process of making carborundum. His method is simply to take petroleum coke, common gas coke, or other kinds of impure carbon, and subject the same to a very high temperature in a large electrical furnace, so that all impurities, &c., are volatilised. This method produces and converts the coke into a very desirable form of graphite, which, on account of its hardness, compactness, purity and conductivity, gives us a raw material best suited for all the requirements to which electrodes are subjected. The author is of an opinion that it will not be long before the Acheson method of producing raw material for making special electrodes, &c., will be adopted, and where cheap water power can be had there is no obstacle to prevent its production on a commercial scale.

CHAPTER VII.

GAS GENERATORS.

Modern carbonising furnaces in which carbons are baked are all worked with gas, which is generated in a sort of furnace called the gas generator. The advantages in employing gas are the following :—

1. The easy regulation of the relation of the fuel and the air necessary for its combustion.

2. The facility with which the air can be mixed with the gas, by which the chemical action that results through combustion is accelerated.

3. The possibility of first heating the air that is used and thereby obtaining a higher temperature, while at the same time effecting an economy in fuel.

It would be practically or commercially impossible to heat the modern carbonising furnaces without using gas.

Principle of the Gas Generator.—Before describing the furnace it will be necessary to investigate the principles of the gas generator, which is one of the most important factors. In order to be able to render the matter clear, the writer has, to some extent, taken advantage of the admirable works of Prof. A. Ledebur and H. Stegmann in bringing many points forward that escape the practical man engaged in the business ; on the other hand there are points and facts that seem so self-evident and simple to one in the business, that he thinks it appears at first unnecessary to review them, but upon consideration one comes to the conclusion it is of vital importance to enumerate them.

The gas generated for such heating purposes is not manufactured in the same manner as the gas used for illuminating purposes, for in such processes the fuel is distilled—that is, the volatile parts are driven off, while coke remains behind. In a gas generator, however, nothing remains behind but ashes. Nor can a gas generator be called a furnace in the common sense of the word, for in an ordinary furnace the product of combustion is carbonic acid gas, CO_2, while the object of the generator is to produce carbonic oxide gas—that is, CO.

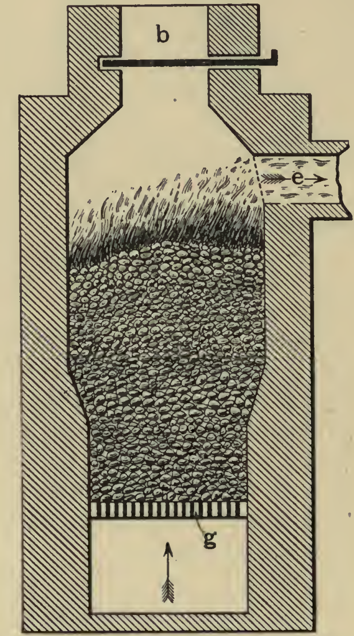


Fig. 32.—Principle of the Gas Generator.

In Fig. 32 we have the principle on which all gas generators are constructed, and it will be seen that in reality it resembles an ordinary furnace or stove, in which there is a high layer of fuel. In the figure, *g* represents the grate on which the fuel is piled up to nearly the orifice *c*, into which the gas issues.

At *b* there is an opening, into which fuel is thrown when necessary. In a gas generator it is of vital importance to keep the fire at a high temperature, by means of which the chemical and physical actions that result in connection with the fuel and air are accelerated. Not a partial but a complete combustion is the principle by which gas generators work in converting fuel into gas.

In an ordinary furnace the heat generated is generally given off to surrounding bodies, or used in one way or the other, whereas in the gas generator the heat, with the product of the combustion (*i.e.*, carbonic acid gas), acts as follows: The heat is imparted to the fuel over it, which gets heated to a high temperature, which dissociates it, causing any gases or hydrocarbons which the fuel may possess to be liberated and pass upwards. The carbonic acid gas which was formed, in passing this heated mass of carbon or carbon vapour, takes up another atom of carbon, and is converted into carbonic oxide gas. The fact that a great heat is necessary when reducing carbonic acid gas into the oxide gas is shown from the following theoretical considerations: The combustion of 1 kilo of carbon, C, produces about 8,080 thermal units (1 thermal unit being the heat necessary to raise 1 kilo of water from 0°C. to 1°) when transformed into carbonic acid gas, or when reduced into carbonic oxide gas gives about 2,473 thermal units. Now, in the reduction of carbonic acid gas into the oxide one atom of carbon is taken up by the carbonic acid, and we have $C + CO_2 = 2CO$. As this one atom of carbon is fixed, it cannot be liberated before it has received sufficient heat, which heat is supplied from the combustion that produced the carbonic acid. Now, when we have the conversion of one part by weight of the carbonic acid gas into two parts of the oxide we have $2 \times 2{,}473 = 4{,}946$ thermal units, which, when subtracted from the 8,080 that the carbonic acid gas produced, leaves us 3,134, which represents the work done in converting the carbonic acid gas into the carbonic oxide gas. This heat, which is necessary for the conversion, must thus be present in the generator.

This conversion is, however, only one part of the action going on in a generator, as the fuel, when it is coal, wood or turf contains other hydro-carbons with water perhaps, all of which are distilled by the action of the heat, which shows us again where some of the heat is also expended and absorbed. The nitrogen that comes into the generator with the air passes upwards and mixes with the other gases, so that the gas used in heating the oven, or rather for carbonising, really consists of a mixture of several gases, some of which, like the carbonic acid gas and the nitrogen, may be called dead gases, as they do not support the combustion.

If only coke is used as fuel in a gas generator we do not obtain such a mixture of gases as mentioned above, as the hydro-carbons have already been driven out of the coke, which is, in fact, pure carbon, containing also a little ash. In this case, if we suppose that no carbonic acid gas escapes, and that all is converted into the carbonic oxide gas, we obtain in weight or volume 34·3 parts of the carbonic oxide gas and 65·7 parts of nitrogen. 1 kilo of such a mixture when burned —that is, when its carbonic oxide is consumed by being converted into carbonic acid gas—gives about 824 cal. or thermal units, while a cubic metre will weigh about 1·25 kilos. Of course, in reality these figures are lower, as there is always some carbonic acid gas that escapes and more air taken than is necessary. It must be remembered that air contains about 21 parts of oxygen and 79 of nitrogen, from which we see that an over-abundance of air, of which the oxygen is not all consumed, brings quantities of nitrogen with it that dilutes and weakens our gas, so that it produces less thermal units per volume when burning. One of the main things in working a generator is to see that the fire is even throughout its whole cross-section, for if there is a spot where the fire is weak or where there is none at all the air will ascend without doing any work, and passes into the passage that leads to our oven. Not only does such air weaken the thermal qualities of the gas, it is also dangerous, as an explosion may follow from the formation of oxy-hydrogen.

It is well known, and has been proved by experiment and practice, that the conversion of carbonic acid gas into carbonic oxide gas is accelerated by maintaining a high temperature in the generator, while at the same time the hot fuel should have a large surface with which the gas can come into contact. This influence of a high temperature is shown by the following table, where charcoal was subjected at various temperatures to a current of dry air* :—

Charcoal at	Weight of carbonic acid produced.	Weight of carbonic oxide produced.
350°C.	85·2	14·8
440°C.	80·4	19·6
520°C.	79·6	20·4
700°C.	72·4	27·6
1,100°C.	2·2	97·8

This table shows conclusively that, when care is not taken in handling the generator, so that the temperature of the fire is low, we produce very uneconomical conditions, as we obtain at low temperatures an abundance of carbonic anhydride gas which does not support combustion, while our object is to produce the oxide gas, which, as we have already shown, requires a high heat. Akerman found that when passing carbonic acid gas over charcoal he obtained the following results:—

At 319°C. he obtained 0·0% of carbonic oxide gas,
At 393°C. „ 0·4% „ „
At 918°C. „ 13·0% „ „

which results confirm our previous remarks. At low temperatures there is also a great deal of vapour generated when using certain kinds of fuel, which afterwards condenses in the form of tar, &c. This settles in the pipes or passages, which get clogged up while the working efficiency is low.

Stöckmann analysed the gases from a generator worked first with a good high-temperature fire and then with a low-temperature fire, and obtained the following results :—

—	High temperature test weight.		Low temperature test weight.	
Carbonic oxide gas	21·73	fuel gas	16·56	fuel gas
Olefiant gas	2 95		1·32	
Methylic hydride	0·58		1·29	
Hydrogen	0·47		0·27	
Carbonic acid gas	7·41	inert gas	12·14	inert gas
Nitrogen	66·86		68·42	
	100·00		100·00	

These tests show how important it is to work the generator at a high temperature, and from the figures it can be shown

---

* *Stahl und Eisen*, 1882.

that at a high temperature there is gas generated which possesses about 37 per cent. more heat than at a low temperature. It is therefore necessary always to keep a brisk fire going, and to keep the fuel at a constant height by frequent stoking. The greater the height of fuel in a generator the better, as long as it does not offer too much resistance to the passage of the gases, or does not go over the orifice into which the gases pass.

The influence of the surface presented by a fuel is also marked. The more compact a fuel is, the less surface we have, the slower is the conversion of the carbonic acid into the oxide. Bell obtained the following results when passing carbonic acid gas over red hot hard coke, soft porous coke, and charcoal:—

—	Hard coke volume.	Soft coke volume.	Charcoal volume.
Carbonic acid gas......	94·56	69·81	35·2
Carbonic oxide gas ...	5·44	30·19	64·8

Fuel in small pieces seems therefore better adapted than that in large pieces, as weight for weight the fuel in small pieces presents more surface, yet it must not be so small that there is undue resistance offered to the passage of the gases. One of the best ways of keeping a high temperature in a generator is by keeping a good supply of air that feeds evenly at all points in the cross-section of the generator.

The amount of fuel converted into gas in a given time, on which also the temperature depends, is proportional to the amount of air supplied, which depends on the draught and the resistance offered to the gases in their passage through the layers of fuel. The air is generally supplied to the generator by means of a blower, and in such a case can be regulated so as to force any amount of air that is necessary to overcome the resistance offered to the gases in their passage. Another advantage in using a blower is that the pressure of the gas is higher than it would be if only a chimney draught was used, and the chemical actions are better performed.

Another good way is to so build the generator that there are small channels around its sides through which the air first passes before it enters in at the grate. By this means the air gets warmed up, which means economy. The temperature at which the gases issue from the generator depends, of course, upon the nature of the fuel used and upon the care taken in handling. Fuels that have already been carbonised, as coke, charcoal, &c., produce hotter gases than those fuels which are composed of hydrocarbons that must be decomposed first by the generator, thereby absorbing large quantities of heat which could be otherwise taken up by the gases, while a good draught from the blower which generates large quantities of gases helps to attain a high temperature. Bunte found that by using coke, and having a draught of about – 7mm. to – 8mm. on a water manometer, the temperature of the gases issuing from the generator was about 1,000°C. Gas generators are built in different forms, as the construction depends upon the nature of the fuel it is intended to use. In fuel we have a great variety, including coals of the anthracite and soft kinds, coke, charcoal, lignite, peat, turf, wood, sawdust, &c.

Coke or charcoal gives the least trouble as they do not form much ash and do not cake or slag as do many of the coals. When broken into small pieces we obtain an even mass that presents a large surface, and we get a gas that issues at a

—	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Thermal units contained.	Moisture contained.	Ashes contained.
	%	%	%	%	Cal.	%	%
Wood	50·5	6·2	42·3	1·0	3,600	20	2
Turf	60·0	6·0	32·0	2·0	5,000	25-30	6-20
Lignite	61·5	5·5	33·00		5,500	25-40	5-15
Brown coal	69·5	5·5	25·0		7,000	5-10	3-15
Bituminous brown coal	75·5	5·5	19·0		8,000	4-8	3-10
Mineral coals—							
(*a*) Giving long flames, not caking and dry	77·5	5·5	17·0		8,200	2-4	2-15
(*b*) Giving long flames caking (gas coal) ...	82·0	5·5	12·5		8,600		
(*c*) Ordinary coal that cakes	86·5	5·0	8·5		9,000		
(*d*) Small flaming coal that cakes	89·5	4·5	6·0		9,400		
(*e*) Lean anthracitic coal	92·0	3·0	5·0		9,200		
Anthracite coal	94·0	2·0	4·0		9,200		

high temperature, while there is no danger of distilled matter condensing in the passages that lead to the oven. No doubt charcoal is too expensive; but there are many countries where coke is as cheap as coal, or cheaper, and in such places it would be advisable to use it. One of the main points in a fuel is the quantity of carbon it contains, and preference is to be given to that fuel whose unit weight of carbon costs the least. Most of the other fuels contain also hydrogen, oxygen, nitrogen, moisture and ash. Prof. Ledebur gives the table on previous page, showing the various composition of fuels.

The table below shows approximately the volume and weight of gas that can be obtained from 1 kilogramme of fuel, supposing it to be free from ashes and moisture, and including also the carbonic acid gas and nitrogen:—

Coke or charcoal	will	produce	about	6·5cbm.	=8	kg. of gas.
Wood	,,	,,	,,	2·2 ,,	=2·8	,,
Turf and lignite	,,	,,	,,	2·8 ,,	=3·4	,,
Brown coal	,,	,,	,,	3·4 ,,	=4·0	,,
Mineral coal	,,	,,	,,	4·5 ,,	=5·4	,,

From this table we can see at a glance the advantage of using coke in the generator when it can be procured relatively as cheaply as other kinds of fuel. Coke, charcoal, wood, turf and coarse brown coal generally retain their form when in the generator, only shrinking more and more together, until they are at last reduced to powder, which falls either through the grate or gets mixed with the ash. Many other kinds of fuel, however, when heated, begin to split or crack, falling into small pieces, as lignite and some coals of the anthracitic class, and also some of the coals that are rich in gas and do not cake. When such kinds of fuel form high layers it may happen that this splinting and breaking of the material may clog up the passages that are necessary for the gases in ascending, hindering the conversion of the gases, and thus diminishing the quantity. Such fuel is used in generators with special grates.

Coals that get soft when heated, or cake together into lumps, also often render it difficult for the gas to ascend, as they clog up the passages, rendering the use of a blower necessary to overcome such obstacles; in fact, as has already been mentioned, the form of the generator depends upon the fuel used.

Prof. Ledebur, in pointing out the influence of moisture or water in the fuel on the temperature obtainable, when the gases produced from various kinds of fuel are burned, arrives at the following figures, supposing that the temperature of the gases and air as they reach the oven are at 0°C.:—

From	fresh-cut wood the gases can produce about...	1,412°C.
„	air-dried wood „ „ „ ...	1,600°C.
„	well-dried wood „ „ „ ...	1,704°C.
„	peat or lignite „ „ „ ...	1,642°C.
„	dried peat „ „ „ ...	1,774°C.
„	old brown coal „ „ „ ...	1,737°C.
„	mineral coal „ „ „ ...	1,896°C.

From this table we see that it is economy to use fuel containing as little moisture as possible. In the above calculated temperatures it was supposed that the gases and air entered the oven at 0°C., whereas in practice they generally enter the oven at a high temperature, so that the real temperatures are higher than the table gives. The fuel used in a generator should always be stored under a shed, and, if possible, dried before using, especially such porous fuel as coke.*

Figs. 33 and 34 show the construction of modern gas generators.† These are used largely in metallurgical works, and supply the gas for Siemens and Martin furnaces, where a high temperature is obtained. As carbonising furnaces or ovens require about the same heat, these generators, especially the one shown in Fig. 34, are mostly used in carbon works. Fig. 33 shows a generator, designed by A. Cramer in Saxony, that is suited for coke, or a mixture of coke and coal. The dimensions marked in the figures are in metres. At *a* the air is supplied by means of a blower, in which case, of course, the door *b* must be closed. The gas that is generated takes the path *c*, *d*, *e*, and *f*, when the valve *g* is open. The door *h* serves for cleaning purposes, while *i* is a small water reservoir into which the pipe *d* projects and serves for catching up condensable matter, while, in case of an explosive, it will afford an easy egress for the explosion gases. The same may be said of the door at *g*, which, in case of an explosion, will fly open. The

---

* For further information concerning fuel, &c., *see* Mr. E. Tremlett Carter's "Motive Power and Gearing" (*The Electrician* Series).

† "Gasfeurungen." By Prof. A. Ledebur.

fuel is thrown in at *j*, and is then allowed to fall into the generator by raising the handle *h*. This lowers the valve *k*, and allows the fuel to pass. The object of such devices is to prevent air from getting into the furnace. As will be seen,

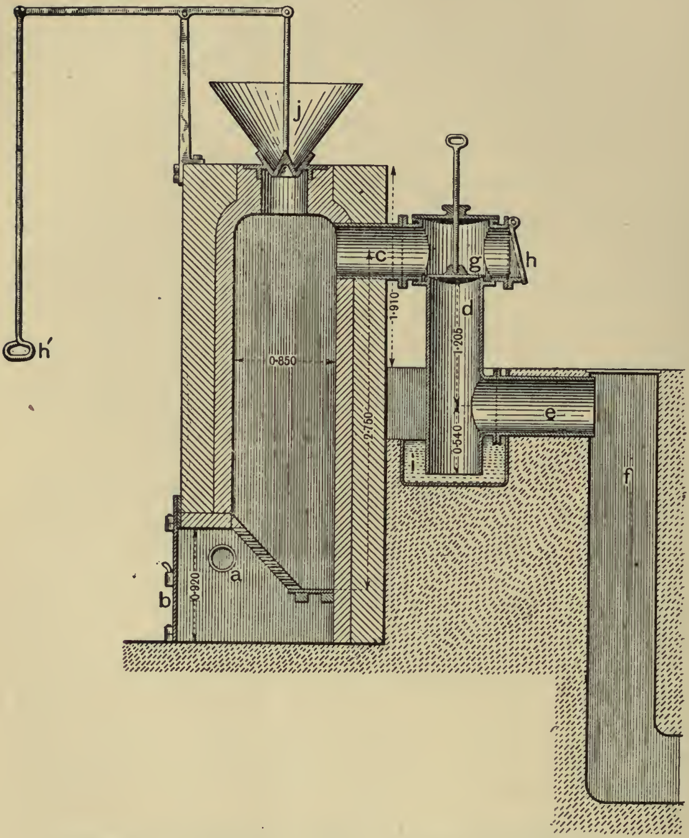


Fig. 33.—Gas Generator designed by Cramer for using Coke or a Mixture of Coke and Coal.

the grate is of the "step" form, while the inner cross section of the generator is circular. The passage *f* leads to the furnace where the gas is consumed. The generator should be close to the furnace so that the gases may arrive there as hot as possible. Bunte, who made some tests upon the fall of temperature that gases undergo in the passage leading to the furnace, found that it was possible for the gases to cool down from 50 to 75°C. per metre. Of course, this drop in temperature depends upon the temperature the gases have when leaving the generator, that of the air, their velocity, and the material of which the passage is made. It is, therefore,

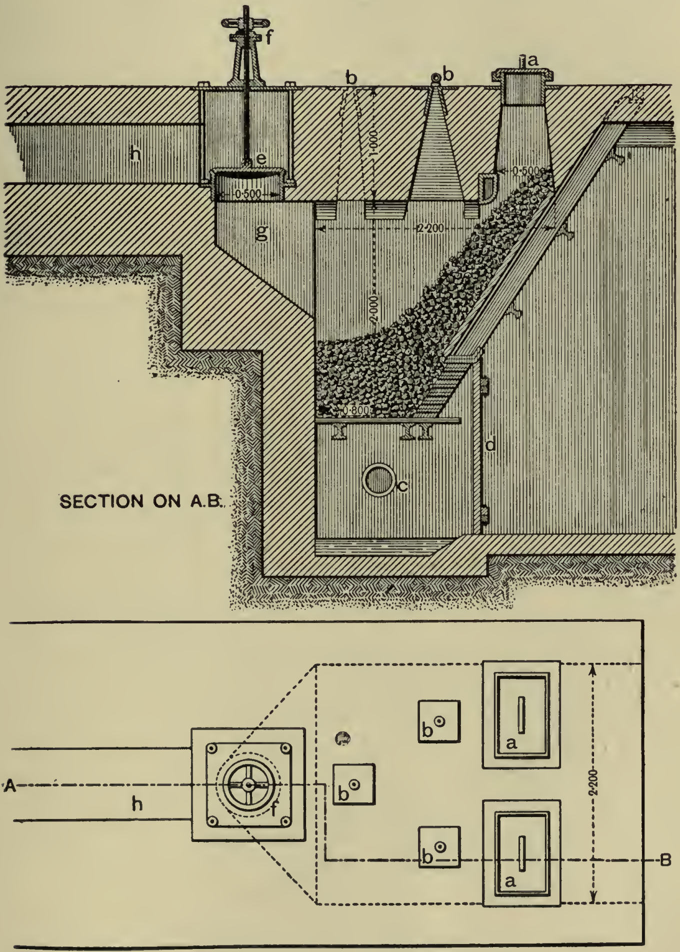


Fig. 34.—General Form of Gas Generator.

best to build the passages in the earth so that they retain the heat which they receive from the gases, while it is advisable to give them a slightly inclined position, so that any condensable matter which may settle in them will flow into a drainage pipe.

The gas generator shown in Fig. 34 is largely used in practice; although there are many different designs, the principle of its construction and its form are about the same in all. It is largely used also in connection with Siemens furnaces, and is adapted for small coal, especially for brown or mineral coal, which gives plenty of gas. Fig. 34 is a vertical section and plan. It will be noticed that two of the sides of the generator are vertical, while the front and back sides are inclined. The inclination depends upon the material used as fuel, and may be from 50deg. to 70deg., according as the latter is compact or loose. The fuel is thrown into the generator at *a* by raising the covers, and *b b* are openings that serve for stoking and keeping the fuel evenly divided on the grates. One of the grates, as will be seen from the figure, is a plain one, while the other is of the "step" form, thus insuring a large surface, which is necessary when small coal is used. The air arrives from the blower at *c*, while *d* is a door which is kept closed when the blower is in action, and serves also for taking the ashes away. The gas that is generated goes into the passage *h*, when the valve *e* is raised by means of the wheel *f*. It will also be noticed that the whole generator is built below the surface of the ground, with only a space open at the front in order to get at the ashes, &c. This affords a convenient way of supplying fuel to the generator as the openings *a* are on the ground level, while there is little heat dissipated through the sides, as they are banked with the earth, which is a bad conductor. The dimensions marked in the drawing are in metres.

Fig. 35 shows the construction of a gas generator that Stegmann says is adapted for nearly all kinds of solid fuel with the exception of earthy brown coal. A noticeable feature of this generator is the grate, seen in the illustration. Of course, when using a blower, it is necessary to have a door in front of the grate. The advantages of such a form of grating is that there is a constant tendency of the fuel as it gets consumed to shift downward, while the ashes, &c., get pushed towards the opening between the grate and the back of the generator, from whence they can be easily dislodged. A small opening at the top of the generator (not shown in the illustration) serves for stoking purposes when necessary.

It has, however, been found in practice that fuel which cakes and swells up a great deal does not give general satisfaction when used in the generators that have been so far described. The generators that are built especially for such kind of fuel have generally the form shown in Fig. 36. It will be noticed that the lower portion of the generator is of a plain, cylindrical form, while the upper part tapers inwards. Such generators were built by Sailler for the Witkowitz works, where they use coal that cakes very much, and have given satisfaction with the fuel used. As seen, the generator has no grate; there are simply two openings, *a a*, at the bottom, which are stopped up with plugs of earth when the generator is in action. From time to time these plugs are withdrawn, and the fused slag is allowed to run out. Around the lower part of the generator there are two grooves,

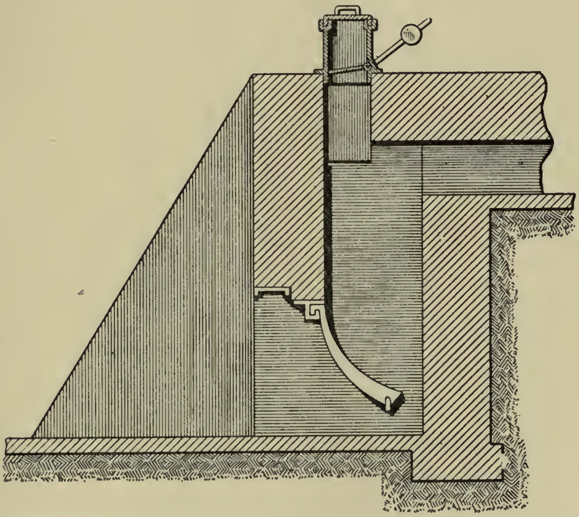


FIG. 35.—Gas Generator adapted for different kinds of Fuel.

b b, in which water circulates for cooling purposes, as that part of the generator gets very hot. The air which is supplied from blowers is led into the generator at two sides by the nozzles *c c*, which are also placed in a cooling box, shown by the shaded portion at the lower part of the generator. At the top there are a couple of stoking holes, *d d*, while *e* is the

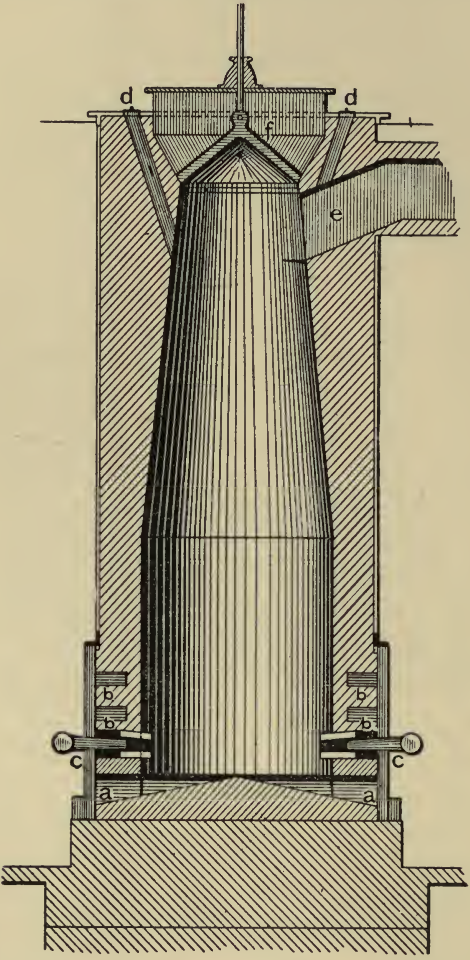


Fig. 36.—Gas Generator for Caking Fuel.

passage into which the generated gases flow, and *f* is a device for supplying fuel, similar to that already explained. It is said that, with an air pressure of about 10cm. to 20cm. on a water manometer, the gas generated does not contain more than 1 to 2 per cent. of carbonic acid gas, while the temperature at which it leaves the generator is from 700°C. to 900°C. Nor is there any distilled matter obtained, as the gases are so hot when they reach the furnaces that the volatile matter cannot condense.

Mention ought to be made also of the Gröbe-Lürmann gas generator, which differs somewhat from the forms previously described. In this generator there is a compartment resembling a retort, into which the coal is fed by mechanical means. In this retort the coal is distilled in a manner similar to the process worked in illuminating gas works. As fresh coal is supplied into the generator the coke that is formed is pushed backwards into another upright compartment, where it is converted into gas as in other generators. Thus the action of the Gröbe-Lürmann generator is first to obtain what gas the coal contains by distillation, and then convert the coke that remains into gases by the ordinary generator process. The heat used for the distillation is that of the gases that are generated, which are led through a flue encircling the retort. These generators have given general satisfaction, but they are more expensive to build and maintain; the fact that mechanical power is necessary for supplying fuel has also somewhat retarded their employment generally, although there are some ironworks and glass factories that use them.

We have seen that, in most of the generators shown, the fuel is supplied by a special device that tends to prevent the air from getting into the generator. In Fig. 37 we have a cross-section and side view of such a simple contrivance that is in general use and can be recommended. The cover *a* is lifted off and the fuel is filled in the space *b*. The cover is then replaced, the lever *c* is turned in the direction of the arrow; this opens the passage and the fuel falls into the generator, thus allowing very little air to get in.

According to Steinmann, the total grate surface of a generator should not exceed two square metres, and if more gas is wanted than one generator can produce, two should be used as large generators do not work well. The space between the grates should be about $\frac{1}{4}$ to $\frac{1}{3}$ the total grate surface in a plain grate, and $\frac{1}{2}$ to $\frac{3}{4}$ in those of the step form. Prof. Ledebur states that upon one square metre of grate surface about the following amount of fuel should be supplied per hour: Mineral coal about 40 to 50 kilogrammes (and if there is a strong draught about 60 kilogrammes), coke 60 to 80, and peat 100 kilogrammes.

The height of the fuel in a generator may be about 0·6 metre with small brown coal, 0·7 metre with large brown coal, 0·75–0·8 metre with mineral coal and coke, and 1–1·5 metres with peat and wood. It is almost needless to state that every generator should be supplied with some safety device, as, for example, that shown in Fig. 33, so that in case of an explosion the expanded gases may find an easy path for egress.

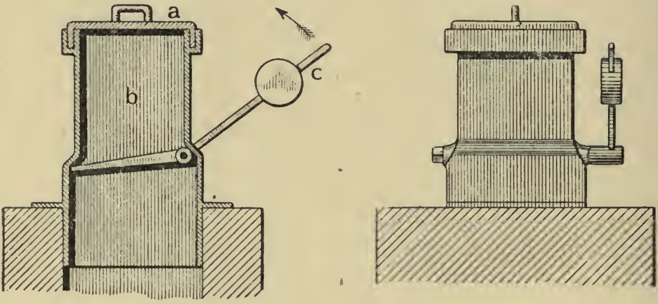


FIG. 37.—Device for Feeding Fuel into Generator.

In concluding this chapter on generators the author wishes to point out what an advantage over other countries the United States and Russia possess, as they have enormous wells of natural gas, and gas generators are, of course, not necessary where natural gas is available. There is thus a saving in attendance, while at the same time the flow of gas is far more regular than can be obtained from a generator which depends upon cautious manual management. Natural gas has another important advantage. That obtained in the United States contains much less inert gases than that generated in a generator, and, therefore, per weight or volume it will give more thermal units than the gases produced in a generator, so that the natural gas is better adapted for obtaining the high temperature necessary in baking carbons. The gases generated in a gas generator may have, under good conditions, 35 parts in volume of fuel gases, the remaining 65 parts consisting of nitrogen, carbonic acid gas, &c., while natural gas contains more than 80 per cent. of fuel gas. The components of natural gas are: Methane (CH_4), hydrogen (H), ethylene (C_2H_4), ethane (C_2H_6), carbonic acid gas (CO_2), and nitrogen (N).

CHAPTER VIII.

THE FURNACE.

In considering the furnace or oven in which the gas is burnt, it may be said that this apparatus is, in reality, nothing more than a simple chamber, or part of one, in which the gases and air meet, get mixed, and then burn, while the resulting gases that are produced by the combustion leave at the opposite end. The principal object to be attained in such a combustion chamber is to effect a complete burning of the combustible gases—that is, the combustible hydrocarbon gases should all be transformed into carbonic acid gas. If carbonic oxide gas escapes into the flue, it means so much loss, or, more accurately, when carbonic oxide gas, carbon, hydrocarbons or hydrogen escapes, we have incomplete combustion. To obtain complete combustion, we must have a sufficient and well distributed supply of air, also a high temperature, which facilitates the chemical action resulting from the mixture of oxygen and the combustible gases. One of the most important objects to attain is to get the gases and air well and proportionately mixed, as otherwise we obtain an incomplete combustion. The author may cite the two cases of an illuminating gas jet and a Bunsen burner, both of which, let us suppose, consume the same quantity of gas. The heat given out by a gas jet in such a case is considerably less than that of the Bunsen burner, where the gas and air get well mixed before burning, while, in a gas jet there is only a sort of lateral mixing of air and gas. We see also that a much better mixing of air and gases can be obtained when the gases are supplied from a generator or gas well than when using an ordinary grate furnace where the fuel is directly burned and converted into heat.

From these facts we conclude that an ideal furnace, especially for the carbon industry, would be one in which the gases issue from a large number of jets, which permits a better and more perfect mixing with air, while at the same time the heat produced will be more evenly distributed than when only one or a few jets are used. In fact, it has been demonstrated that when a certain quantity of gas is consumed, a better thermal efficiency is obtained when using many jets than when using a few. Another important object to attain when burning gases in an oven or furnace is efficient regulation—that is, to so regulate the quantity of gas that it flows out of the jet or burner in proper proportion. In using the word "jets or burners" the author refers to the openings in furnaces from which the gases or air issue. Frederick Siemens maintains that it is necessary for each flame to have a certain space in which it can expand, otherwise there will not be a complete combustion. His assertions are based upon the theory that combustion depends upon a sort of molecular motion, and that this motion is rendered difficult when gas and air come into contact with fixed bodies, where either attractional or frictional resistance is experienced. Practice has confirmed this view, as it is found that furnaces with a very small combustion space, in which the flames always strike or come in contact with the sides, do not give as much satisfaction as those furnaces having a correspondingly larger space.

We can easily see how important is the regulation of the gas and air in a furnace when, for example, we light a Bunsen burner. At first, we usually obtain a bright flame when the gas is turned full on; we then regulate the quantity of gas so that the flame produced gives only a pale blue light, and thus obtain the best heating flame with a smaller quantity of gas. These same facts apply to furnaces, although in practice it is often very difficult to provide proper means of regulation for each jet in a furnace, as in most cases a set or row of burners are regulated by means of one valve.

To obtain a high temperature in a furnace it is necessary to have the air heated before it is mixed with the combustible gases. It is evident that when cold air is supplied a large quantity of heat is absorbed and taken from the fire, which heat would otherwise have been used for a more direct purpose. Mr. Neilson, of Glasgow, was no doubt the first to propose the hot blast—that is, to heat the air used for combustion before it reaches the furnace. His contrivance consisted of a series of pipes that were maintained at a high temperature, either by means of a separate furnace or by using a portion of the waste heat of the blast furnace itself. It was, however, in this direction that William and Frederick Siemens in 1860 made their epoch-making invention of what is known as the "regenerator." This invention consists simply of a chamber that is filled up with fire bricks so piled upon each other as to allow the heated gases of combustion to circulate freely around them before passing into the flue and out at the chimney. Generally, in practice, two such chambers are provided; as soon as the bricks in a chamber are red-hot the combustion gases are switched over to the cold chamber in order to heat it. The air necessary for combustion is allowed to pass into the furnace by way of the hot chamber, and thus its temperature is raised to about 600°C. or 700°C. before it mixes with the combustible gases, thereby making it possible to obtain a very high temperature. As soon as this chamber is cooled down somewhat, the other chamber, which in the meanwhile was heated, is switched on to the air passage again. Thus, by forcing the air always to pass through one or the other hot chamber, a constant supply of hot air is obtained for combustion. In certain cases in practice the combustible gases are also forced to pass through such hot chambers, and thus air and gases arrive at the furnace with a very high temperature.

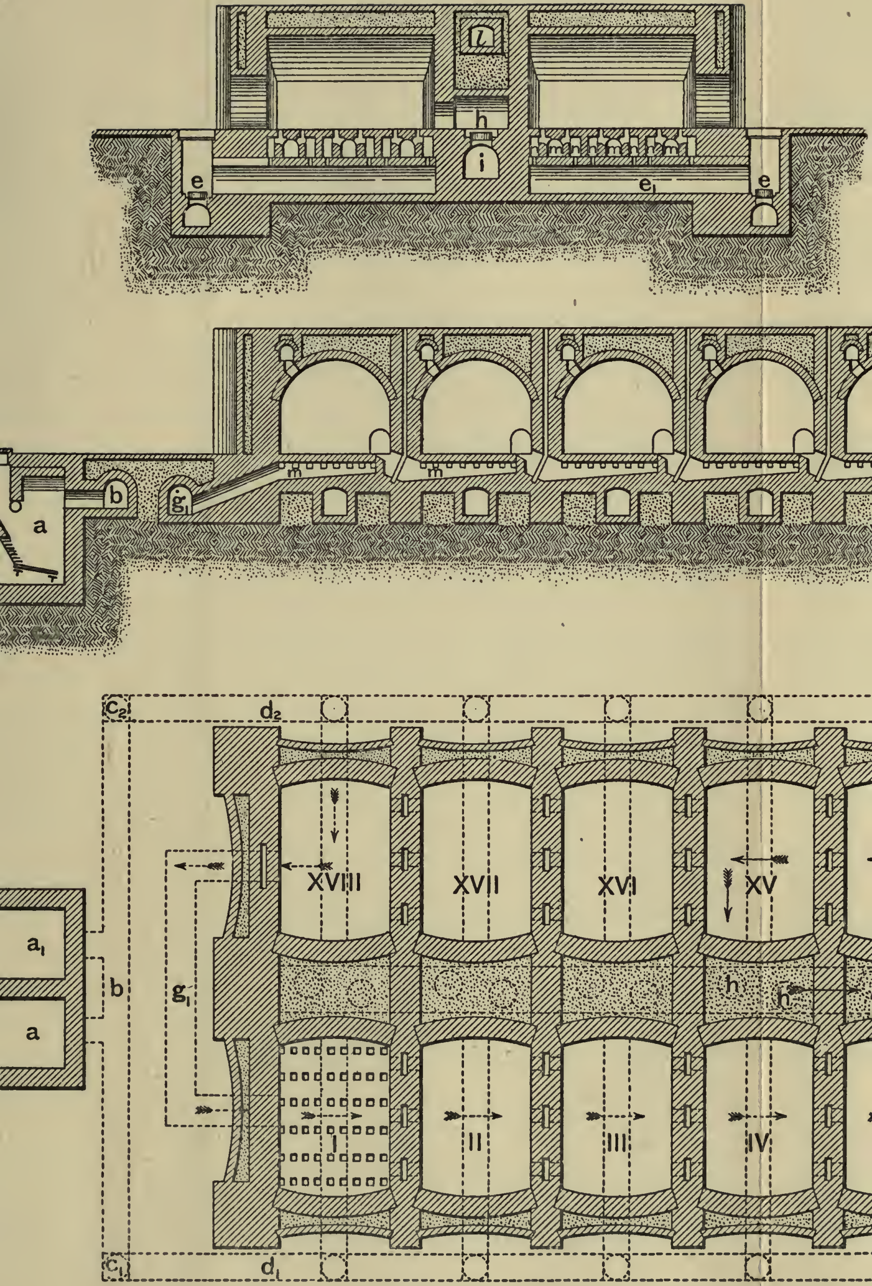
In such cases four chambers are necessary—that is, two pairs, each pair consisting of two chambers, one for the air and the other for the gases. These chambers are heated by allowing a portion of the waste heat to pass through each chamber. By this means it will be seen that a larger portion of the waste heat can be advantageously utilised again, and thus not only is a considerable economy in fuel obtained, but also a higher and steadier temperature. However, even when using a regenerator, the waste heat escaping from a furnace may still be considerable, as tests have shown that the gases coming out at the chimney have sometimes a temperature from 400°C. to 600°C.

Engineers have devoted a great deal of time to this question during the last 30 years, and their experiments have been so far successful that it is possible at the present day to build a furnace or series of furnaces which give very economical results, as nearly all the heat created can be effectually utilised.

If we investigate the conditions and requirements necessary for the baking of electric light carbons, &c., we find that many of these conditions are practically the same as those necessary for baking high-grade ceramic articles. We find that in both cases one of the most important conditions in order to attain success is that the heating of the furnace should be very gradual, and that the rise in temperature should only proceed by small degrees, and not by jumps, as the goods will warp or get contorted. The cooling must likewise be gradual, or else there will be many breaks and cracks. The heat of the furnace must also be evenly distributed, as otherwise we shall obtain an uneven and irregular quality of ware. The nearer we can fulfil and accomplish the above principal conditions, together with that of a high temperature, the more satisfactory and perfect will be the quality of the carbons when baked.

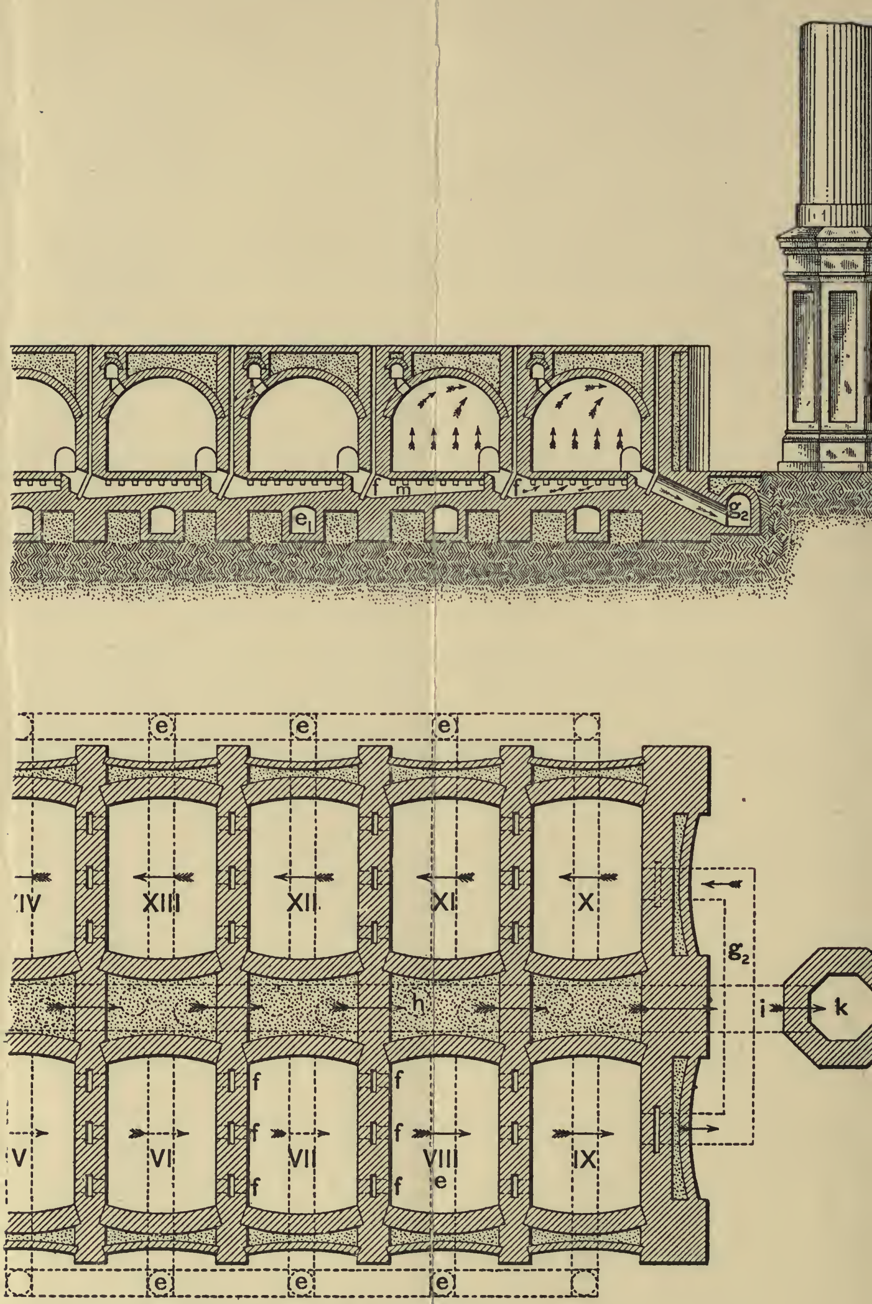
In glancing over the history of the numerous experiments that were made with furnaces of different design in connection with the pottery industry, we find that on the whole two great strides were accomplished—first, in the construction of the "ring furnace system"; and, secondly, that of the "chamber furnace system."

To Herr George Mendheim, of Munich, one of the most celebrated furnace engineers of Germany, is due the credit of inventing the ingenious gas ring and chamber systems of furnaces that are in wide use on the Continent. Herr Mendheim's experience extends to nearly 40 years, and he was the first to convert and adapt the ring system of furnaces so that they could be worked with gas, thus making them applicable for use in the higher branches of the pottery industry. Formerly it was impossible to use them on account of the articles getting soiled by the soot and smoke that was caused



FIGS. 38—40.—Ground Plan, longitudinal section and tra

To face page 115.



nsverse section of Mendheim's Chamber Furnace System.

by direct heating or combustion of the fuel in the furnace itself. No doubt Mendheim's experience with the ring system, and the information he imparted to his friend H. Escherich at the time, resulted, to some extent, in the construction of the well-known Escherich gas-ring furnace.

When the carbon industry began to flourish, in the eighties, some of the keen-witted manufacturers in Germany soon saw that the chamber or ring systems of furnace, mentioned above, were the only kinds to use in which economical and commercial results could be obtained in connection with the carbon industry, and it was not long before they had such systems in their works. It is almost impossible to believe that, after all these years and experience, there still exist some carbon manufacturers that have neither a ring or chamber system in their works. These manufacturers use principally ovens that are known under the name of "periodical half-gas furnaces," which are, as has been explained in the chapter on carbons making, very uneconomical in every respect when used for carbon manufacture.

Saving and economy in handling of fuel, gradual increase of the intensity of heat, and gradual cooling of the wares can only be effected commercially in furnaces on the chamber or ring systems, as they work and are heated *continuously* and not *periodically;* at the same time the heat of the finished goods is utilised and won back again by allowing the air that is necessary for combustion to pass through the finished chambers, thus getting heated up in a similar manner as in a regenerator, while a gradual cooling of the carbons takes place.

In Figs. 38 to 40 we have various views of a Mendheim furnace that contains 18 chambers. The gas generators are shown at *a a*, and it will be noticed that they are somewhat similar in design to that shown in Fig. 34. The gas coming from the generators flows into the passage *b*, and thence either into the passage d_1 or d_2, according on which side of the furnace the chamber that is heated is situated. There are two valves, c_1 and c_2, by which the gas can be turned into either passage d_1 or d_2. From these main gas passages branches extend that lead under each chamber of the furnace system, as shown in this figure at e_1. Let us suppose that chamber VII. has just been finished and that we are going to start chamber VIII. In the first place the gas from the generator flows only along the passage d_1, as the valve c_2 is closed while c_1 is opened. The valve e of the branch passage e_1 at chamber VIII. is opened, and the gas flows into the passage as shown clearly in the transverse sectional view. It will be noticed that the floor of each chamber contains a large number of openings, seen in the plan at chamber I. These openings are just over the dividing partitions of passages m and n (clearly seen in the transverse section), at right angles to the passage e_1. The smaller passages n, it will be noted, communicate with the gas passage e_1, while the larger passages that supply air, communicate with each chamber by means of the openings $f\,f\,f$ in the walls between each chamber, as shown in the plan and longitudinal sections. From the above explanation it will be seen that air and gases meet and mix at the openings in the floor of the chamber, and burn when they issue from it, while the gases resulting from combustion leave by way of the flues $f\,f\,f$ into the next chamber, and so on into the passage g_2, as shown by the arrows in the longitudinal section. From the passage g_2 they enter and circulate through the chambers X. to XV. and then into the flue i, by way of valve h, which is raised. Now the chambers IX. to XV. are filled with carbons that are to be baked, and it will be seen that the heat of the gases that result from combustion is absorbed in the chambers through which they flow, and by this means a gradual heating of carbons takes place. From the flue i the gases escape into the chimney k. The communication between chambers XV. and XVI. is barred by means of sheet-iron dampers placed at the entrances of the passages $f\,f\,f$, so that the combustion gases can only pass out at h into the flue i, and up the chimney.

The air that supplies oxygen for the combustion that is going on in chamber VIII. enters first into the furnace by way of chamber XVIII., as the entrance to that chamber is open; flows through the passage g_1, into chambers I. to VII., and then first into VIII., where it is wanted. The dotted arrows shown in the plan represent the air path, while the arrows drawn in full lines indicate the path that the combustion gases take. It will be seen that as chambers XVIII. and I. to VII. have already been finished, and contain a great deal of heat, the air in circulating through gets heated up to a high temperature, so that when it arrives in chamber VIII. it may be as high as 600°C. to 700°C. This permits us to obtain a great heat in the combustion chamber, and, in fact, about 1,500°C. can be obtained (when using the system invented by Mendheim), at which carbons ought to be baked. Also the fact that the heat of the combustion gases as they pass out of chamber VIII. into the others, where that heat is taken up by the carbons, &c., makes this furnace system one of the most economical yet invented. The fact that over 200 Mendheim chamber furnaces exist in Europe, among which are some in well-known carbon works, speaks for itself, and the work he did for the pottery industry is now keenly appreciated by the best carbon makers on the Continent.

The chamber XVI. in the meanwhile is being filled with fresh goods, while from XVII. the finished and cooled ones are taken away. When chamber VIII. is finished with carbonising, the gas is turned off at e_1, and on at the corresponding valve at IX. The dampers at XV. are removed and placed in position in chamber XVI., while the same is done with reference to the valves h, and thus the operation is continued from time to time, there being a constant shifting, as one chamber is finished, to its neighbour, thus working continuously and obtaining at the same time all the important conditions and requirements that have already been enumerated.

Should the articles that are placed in the furnace contain a great deal of moisture, as is the case with stoneware, &c., an extra passage is built in the furnace as shown at l, from which small branch passages run into each chamber at the top of the furnace, as in the sectional drawings (Figs. 39 and 40). As each branch is governed by a sort of valve, any two chambers can be connected by this means. The object of this extra passage and its branches is, that when a chamber is filled with such damp articles, a portion of the hot air that is circulating through the chambers that are cooling down is led on into this passage, and from there into the above-mentioned chamber, so that a temperature of about 70°C. to 100°C. is obtained, which thus drives off the moisture that is forced to pass into the smoke flue by raising the valve *h* of that chamber slightly. If this were not done the moisture would always condense in the cooler chambers. However, for carbonising electric light carbons, &c., which contain no moisture, such passages are not needed.

It is evident that, when working with such a system of furnaces, it is impossible for a negligent attendant to overheat or suddenly expose fresh carbons to a large heat, as can be done when using a periodical furnace, where the flames, or rather the gas, must first be so regulated that very little heat is produced, or else the carbons will warp (as has already been explained in the chapter on carbons). The fact that the hot combustion gases must first pass through several chambers through which the intensity of the heat is gradually toned down as it reaches the last chamber, insures perfect immunity against risks. The operation of the furnace is very simple, while at the same time it is adapted to be used in many industries by simply making some minor changes, as in the number of the chambers or in different modes of directing the flames, &c.

Articles such as carbons, which are very sensitive to sudden changes in temperature, either increase or decrease, require, of course, a furnace having more chambers than an article not so sensitive, or where warping or cracking is of no account, as is the case when calcinating. A furnace for carbonising electric light carbons, electrodes, &c., should have from 12 to 14 chambers, or a double furnace, as described in reference to Fig. 47, from 24 to 28. The cubical capacity of each chamber depends upon the quantity of carbons that it is desired to carbonise, and Mendheim makes them from 4½ cubic metres upwards. Then, again, the flames, instead of issuing upward from the floor of the furnace towards the ceiling, are generally forced to act in the reverse direction, that is, from the ceiling downwards towards the floor, as far better results have been obtained by this method when baking carbons. Such a modified chamber system is shown in part in Figs. 41 and 42, where *k* represents the mouths or openings from which the gases and air flow out, and, being well mixed, there is almost perfect combustion as the gases are ignited. The flames shoot upwards and then down towards the floor of the oven, and out at the numerous openings *e*, as seen in Fig. 41, the arrows in Fig. 42 indicating the path of the flames.

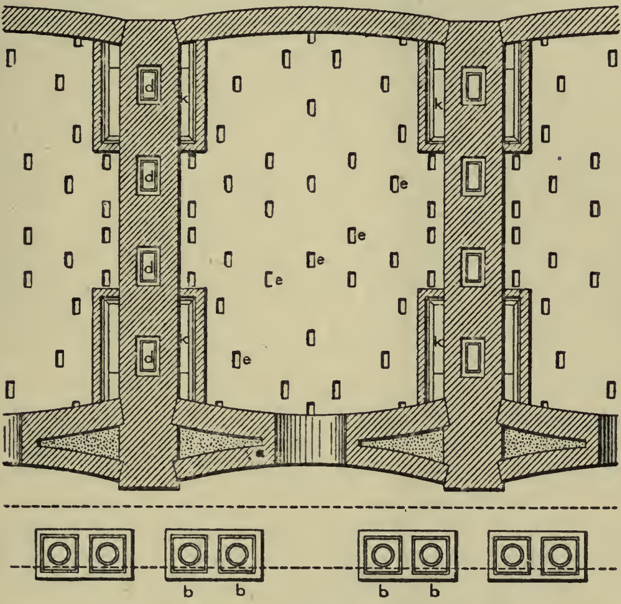


FIG. 41.—Mendheim's Chamber System. Plan.

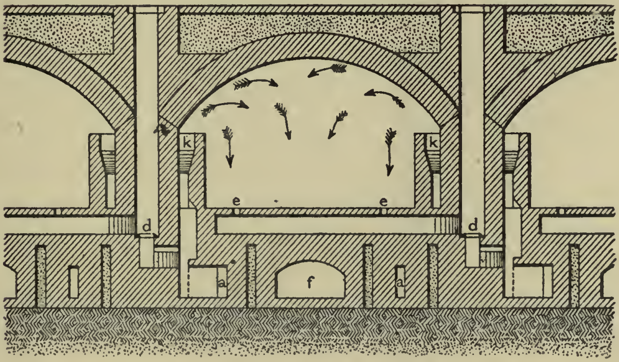


FIG. 42.—Mendheim's Chamber System. Cross Section.

Each of these four outlets *k* is controlled by valves *b b b b*, by means of which the flow of gas can be regulated.

The gas is led to the outlets by way of the passages *a*, while the heated air that is necessary for combustion passes and circulates through the chambers that have already been finished, and thus arrives very hot in the chamber where the combustion is going on, in a similar but reverse direction to that already explained in reference to Figs. 38 to 40. The heated air has to traverse chamber to chamber by way of the valves *d*, by means of which the chamber can be cut off and the smoke or combustion gases made to pass into the flue *f* leading to the chimney. The valves in connection with the flue are not shown in the drawings, but it may be stated that the principle of the furnace, its working, &c., is the same as that illustrated in Figs. 38 to 40, there being only some differences in minor details, such as in the disposition of the air and gas passages, and the direction or path of the flames. From what has been just explained it will be seen that, when retorts containing carbons are placed in such a furnace, the whole are enveloped in flames and get evenly heated, as the fire descending from the top divides, and a portion is drawn into each of the openings *e*. Instead of four outlets *k*, as shown in Fig. 41, two long ones can also be made, extending from the front of the furnace to the back on each side of the chambers. The gas and air is generally led into these outlets in a divided way, so that there are a large number of orifices, each alternate one either for gas or air, by means of which the gas and air get well mixed, this being so necessary in order to obtain perfect combustion.

It will be noticed what an advantage a carbon factory has that is situated in the natural gas regions of the United States, where such a rich and constant supply of gas can always be obtained. It is then possible to effect a better and more individual regulation of each orifice, and at the same time smaller passages or pipes can be used, as the gas is far more pure, containing as it does far less inert gases than that generated in a generator. Neither is there any danger of condensation of tarry liquids, as happens in passages where the gas is generated from fuel containing volatile matter. In fact, the author believes that the time is very near at hand when the United States will not only make all the high-grade carbons they need, but will be able to supply the foreign markets.

Here the author desires to point out what an advantage it would be for those large carbon manufacturers in the States that make the common copper-covered carbon if they would carbonise their goods in a Mendheim chamber furnace. They would soon find out that the quality of their wares would in every respect be improved, while the quantity of their "seconds" would be very much decreased, and at the same time they would effect a saving in fuel. For such cheap articles, or for electrodes, &c., Mendheim builds receptacles made of fire-clay (chamotte) slabs in which such articles can be directly packed, instead of retorts, which are only used for high-grade goods. Of course, in such receptacles a much larger number of carbons can be baked than in retorts. If there is anything that is uneconomical as regards efficiency and effect it is the kiln system of baking used in the States. Mendheim builds furnaces that are used in the pottery industry, containing as much as 25 cubic metres of space, so that for the cheaper kinds of American copper-covered carbons a furnace can be built in which the chambers are of larger dimensions than those used for high-grade goods, thus making it possible to bake larger quantities. However, there is now a marked tendency in the States to use a higher grade of carbon than the coppered ones, that burn so unevenly and give such an irregular light and so much dust.

There is, it should be pointed out, a saving of fuel of over 30 per cent. when using the Mendheim chamber system of furnace as compared with that used in a periodical furnace, while in some circumstances, with a negligent workman, the economy may be as high as 60 to 70 per cent. For very small factories, or such concerns as wish to make their own electrodes (of small size), Mendheim builds chamber furnaces, as shown in part in Figs. 43 and 44. It will be seen that these furnaces resemble the kind that has just been described, with the exception that here we have only two outlets, *k*, instead of four, while the disposition of the passages is a little different to that shown in Figs. 41 and 42. Should a furnace with 12 or 14 chambers be too large for such a factory, six or eight only need be built, but it is then evident that the work cannot be continuous. With so few chambers the work will be intermittent, but when business increases more chambers can be added, so that the working can be continuous. Nevertheless, even with only a few chambers, such a furnace has still a decided economy over a periodical furnace, as some of the waste heat of the combustion gases can still be utilised, although not in such a perfect sense as when working continuously.

There are some carbon manufacturers who employ the gas ring system of furnace, which, like the chamber system, can also be worked continuously, while at the same time there is a similar economy of fuel. Although those conditions and requirements that are necessary for carbonising carbons are also attained in a limited sense in this kind of furnace, on the whole, the chamber system is to be preferred. In fact, one of the leading carbon makers of Europe, who previously worked with the gas ring furnace, introduced a Mendheim chamber furnace when he erected a branch factory in France.

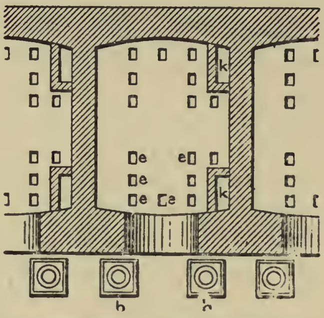


Fig. 43.—Mendheim's Chamber System. Plan.

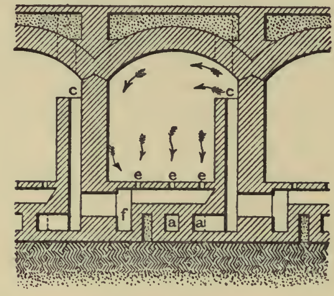
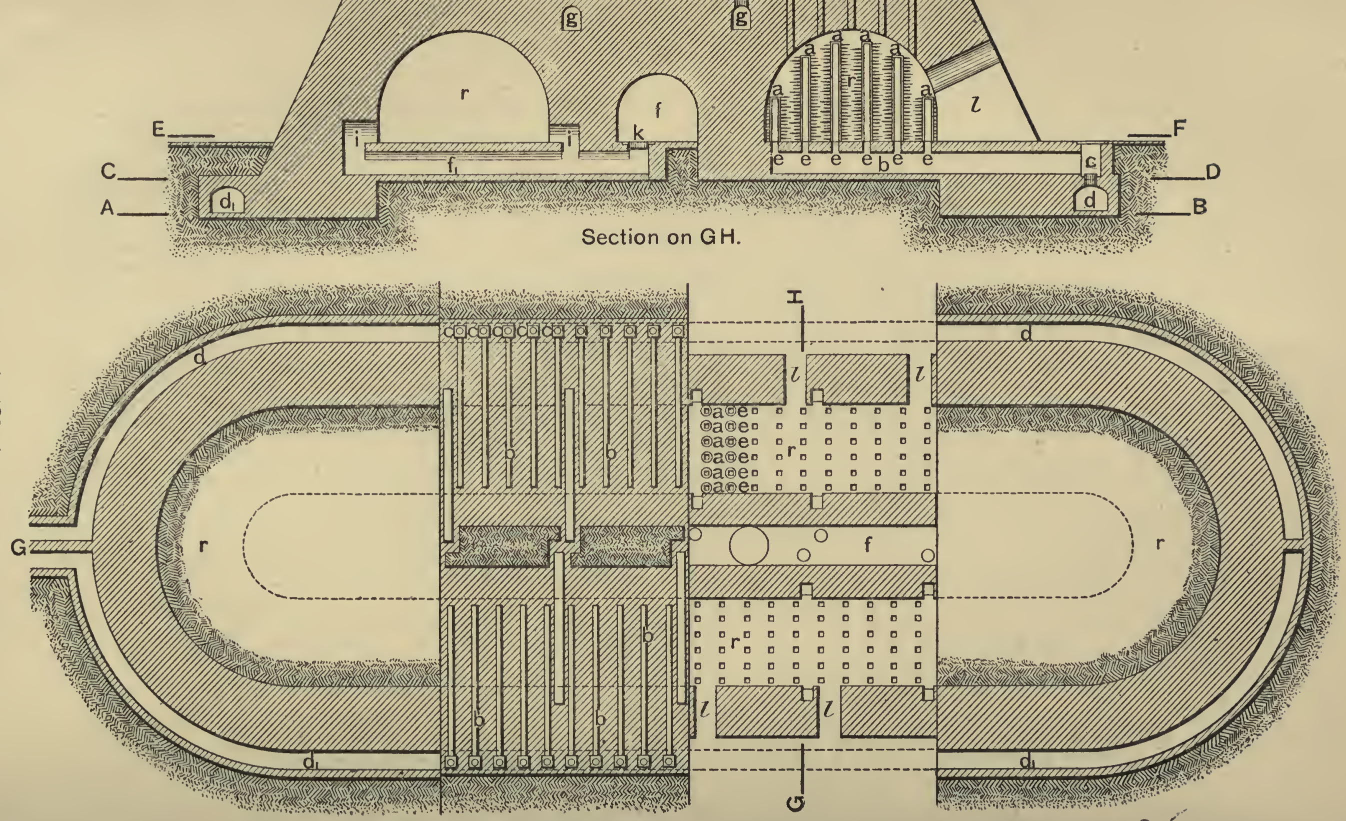


Fig. 44.—Mendheim's Chamber System. Cross Section.

However, as the gas ring furnace is in operation in some of the best-known works, it will no doubt be of interest to describe it. In principle the gas ring furnace is simply a large endless passage in which a shifting fire is always in operation at one part or the other. This passage or ring is generally divided into a number of parts, each part being alternately heated as in the chamber system. The air that is necessary for the combustion does not flow, however, like that in the chamber system, from the bottom or top of a part, or parallel to the gas; on the contrary, it meets the gas at right angles. The air supply simply circulates directly through (in a straight line) those parts which contain the finished carbons, and thus meets the combustible gases that issue either from the floor or sides of the part that is getting heated. The products of combustion continue in the same path until they are forced to enter the chimney flue at some distant part of the ring.

Figs. 45 and 46 represent the Mendheim gas ring furnace, r indicating the carbonising tunnel or ring which is, as can be seen, endless. As shown in the sectional plan, this ring is divided into a number of parts or spaces, each of which is provided with a flue f_1 and branch passages b. The gas enters either the passage d or d_1, according to which part of the ring is being heated. From these main gas passages the branch passages b issue as shown in Fig. 46, and these are controlled and regulated by the valves $c\,c\,c\,c\,c$. Small openings $e\,e\,e\,e\,e\,e$ in the floor of the ring establish communication with the branch passages b. Over these openings are placed pipes made of fire-clay (chamotte), shown in Fig. 45 at $a\,a\,a\,a\,a\,a$, which are closed at the top, but whose sides contain a large number of holes out of which the combustible gases flow, and thus produce a large number of flames, as seen in the drawing. By this means the flames and heat are evenly divided in that part of the ring that is in operation. As already mentioned, under each part of the ring there is a passage f_1, that leads to the chimney flue f when the valve at k is raised. It will be noticed that the exit for the products of combustion takes place at both sides of a section, as shown at $i\,i$. The object of this is to produce an even draught and circulation of air in all parts of the cross-section of the ring. Each section is pro-



Section on GH.

Section on AB. Section on CD. Section on EF. Section on AB.

Figs. 45 and 46.—Mendheim's Gas Ring Furnace.

vided with an entrance *f*, as shown, which is filled up with fire bricks when in operation, and only opened at those parts where the carbons are either taken out or put in. This opening serves at the same time for the air necessary for the combustion section to enter the ring. The passages *g g* serve for the same purpose as that explained in Figs. 38–40, and there designated by *l*, but these passages are not needed when only baking carbons as they contain no moisture. The openings *ppppp* serve as peep-holes, from which the action of the flames, &c., can be observed. The retorts which contain the carbons are placed between the fire-clay pipes *a a*, from which the gas issues, and it will be seen that they are subjected on all sides to a very great heat.

At some carbon works the gas ring furnaces are a little different in construction to those built by Mendheim. In these furnaces the parts of the ring are divided by means of a wall, through which there are many openings so that the air circulation can take place. In these walls, and in the sides of the ring, channels are made that convey the gas from which the flames thus shoot. These furnaces have no side entrances, and the cover or roof of the sections must be hoisted up in order to give access into the interior of the ring. From what has been said it will be seen that these gas furnaces are in reality nothing more nor less than the ring system having the sections divided off by a sort of perforated wall, whereas in the ring system proper the divisions of the ring exist without any such raised partition.

Fig. 47 will give a clear idea of how the Mendheim gas ring or chamber system works when used doubly. Practice has already proved that such a chamber or ring system, when it comprises about 24 sections or chambers, can be used doubly, thus carbonising twice the quantity of carbons in a given time. In other words about 12 to 14 chambers are all that is necessary for a furnace that is built for carbon work. The diagram shows a furnace that Mendheim built for a carbon works in France on the double-chamber system. The main gas passage which is connected with the gas generator is shown at G, from which two passages *a a* branch, one to each side of the furnace. As shown in the sketch, the chambers or part of the ring 1, 1′ to 5, 5′ are supposed to contain

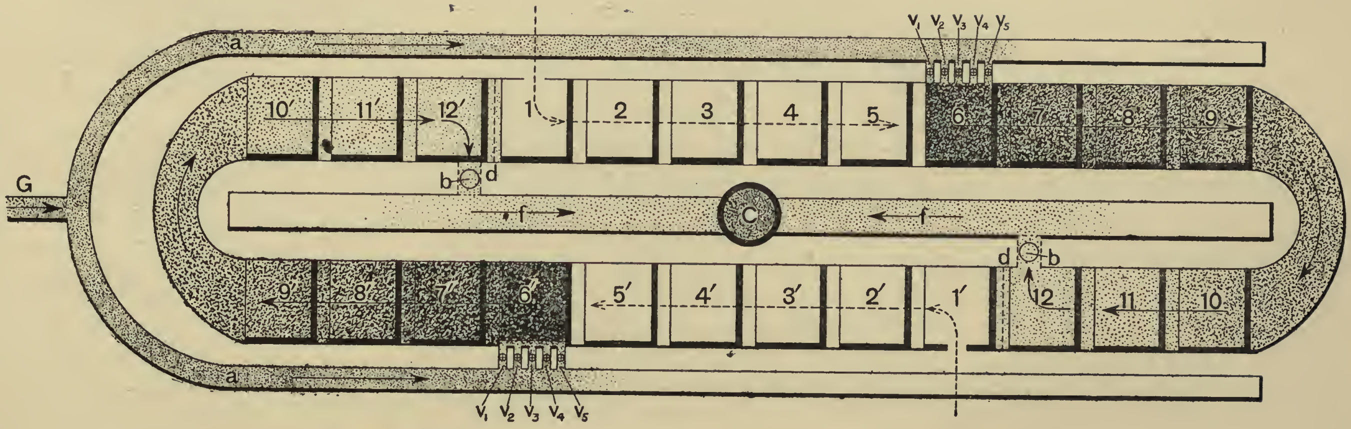


Fig. 47.—Diagram showing the working of the Chamber or Ring Systems.

articles that have already been carbonised, while at parts 1, 1′ the process of taking the finished carbons out and replacing fresh ones is taking place. It will be noticed that at those chambers or sections the entrances are open. In the chambers or parts 6, 6′ the operation of heating is going on as the valves v_1 to v_5 are opened and the gas from the passages *aa* flows into the branch passages under the floor of the furnace at those sections through the openings and into the furnace.

The sections 7, 7′ to 12, 12′ are supposed to contain carbons that have not yet been carbonised, and are gradually getting heated up more or less (according to which part is nearer or farther away from 6, 6′) by the combustion gases as they pass through the parts into the chimney flue *f*. The gradual lightening of the shaded sections from 6, 6′ to 12, 12′ serves to illustrate the fall in temperature, as the heat is absorbed in the parts through which the waste gases must go on their way into the chimney flue. At 12, 12′ there is a damper, *d*, that blocks up the communication with the next chamber or section. In the chamber system this damper is generally of sheet iron, while in a ring furnace it may consist simply of brown paper spread across the ring, as is done in many of the ring ovens that bake common bricks. This shows also how gradual the carbons are heated when first placed in the furnace. The flue valve *b* at parts 12, 12′ are, of course, raised, which permits the smoke or combustion gases to pass into the flue. The air necessary for the combustion that is going on at 6, 6′ enters through the entrances at 1, 1′ and circulates through the hot finished parts from 2, 2′ to 5, 5′, and thus arrives very hot at 6, 6′, where it is deprived of its oxygen by combustion. The dotted arrows in the sketch indicate the air flow, while the full arrows show the path taken by the combustion gases. The gradual cooling off of the chambers or sections that are finished may be seen by the lightening of the shaded sections.

When the carbons in 6, 6′ have been finished, the gas is turned off at the valves v_1 to v_5, while the corresponding valves at 7, 7′ (not shown in the figure) are opened, and the gas in issuing out is ignited, as that chamber or section has already been heated up well. A damper is placed in a similar position across the ring at sections 1, 1′, while the one at sections 12, 12′ can be destroyed, if of paper, by simply igniting it from one of the holes at the top of the ring. The valves *b* of 12, 12′ are closed and the corresponding ones at 1, 1 open. By such successive changes it will be seen there is always a continuous double working of the furnace, which is in operation day and night.

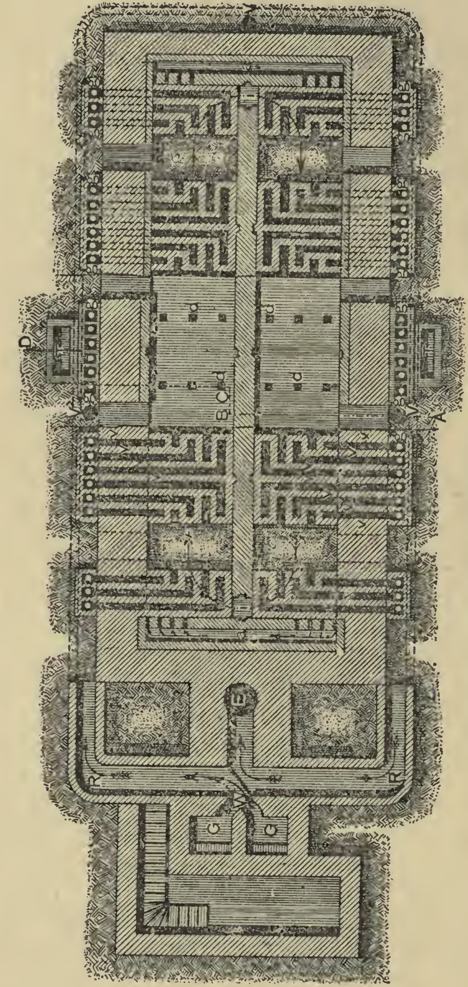


FIG. 48.—Escherich Gas Ring Furnace. Plan.

The gas-ring furnace, constructed by Escherich at a pottery works in Schwandorf, is shown in Figs. 48 and 49,* the latter figure representing a section through A B C D of the plan. This oven is interesting, as F. Meiser, who was Escherich's partner at the time, has since modified and adapted it for carbon factories. The gas generators are shown at G G, and it will be noticed that there is a stairway leading down to the lower part of the generators (which are placed below ground), to enable the operator to get at the grate and clear the ashes.

The main gas-ring passage is shown at R R, and its continuation is indicated by the dotted lines. This passage is divided into four parts by means of the valves V V V, and there is also a small branch passage that leads into the chimney at E. At W there is what is known as a Siemens switch, by which the gas can be made to flow into either side of the passage, according as this switch is turned. The object also in having this switch and the valves V V V is to be able to use the passage for two purposes. A part of the passage can be used for conveying the gas, while the other part serves to conduct the burned gases into the chimney. As seen in the figure, the gas flows into that part of the passage which is on the D side, and, if the middle valve V is closed, prevents the gas from getting into the passage that is situated on the A side. This side is thus used for the present to conduct the products of combustion into the chimney E, as indicated by the arrows.

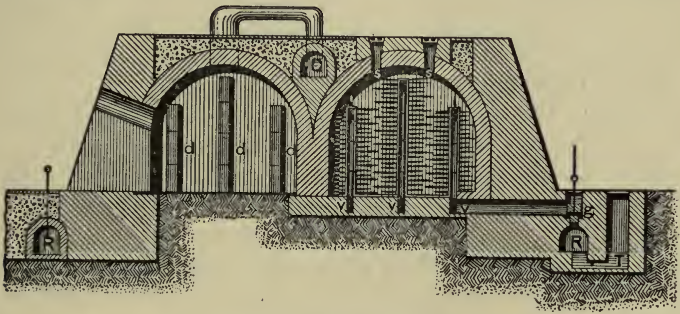


Fig. 49.—Escherich's Gas Ring Furnace. Cross Section.

---

* From Stegmann's "Gasfeuerung und Gasöfen."

From the main passages small branch passages V V V V V V lead under each part of the ring, as shown in a portion of the plan. These have each a valve, *g*, by means of which the gas can be turned on, off or regulated. It will be seen that these valves are so constructed as to obtain an equal pressure of gas at the openings that are in the floor of the furnace. Over these openings fire-clay pipes, *d d d*, are also placed, these having numerous holes from which the gas issues, as shown in the sectional view. The peep-holes *s s* are for inspection. The passage S serves the same purpose as has already been explained in reference to the passage *l* in Mendheim's furnace (Fig. 40), with the exception that communication is made with it to any part of the ring by means of the movable sheet-iron pipe shown on the top of the sectional view. The main passages are built with a slight incline towards the middle, where a drain box, T, is placed ; this catches up any condensed matter that may settle in the passage.

The air that is necessary for combustion, or the products of combustion in passing from one side of the ring to the other, is divided into two paths as shown by the arrows at *a* and *i*, and at the same time a damper made of fire-clay is placed at *i*, so that the flow can be regulated, by which means an even draught is secured at all points in the cross section of the ring. The products of combustion on their way to the chimney leave by way of the clay pipes *d d d* through the branch passages, &c. In fact, the principles and working of this furnace are the same as has already been explained. Entrances to each part of the ring are provided at the sides as shown.

The modifications that were made by Meiser, in some of the furnaces that he built for carbon works, consisted simply in replacing the clay pipes *d d d* that convey the combustible gases by a sort of wall having numerous perforations, and from which a portion of the gas issues, while the other portion flows out of channels that are built in the sides of the ring. Instead of using the side passages for gas and the middle one (as in Mendheim's furnace) for the chimney flue, he simply interchanges, using the middle passage for gas, while those on the outside lead to the chimney. In order to get into the interior of one of his furnaces it is first necessary to hoist up the roof at a part of the ring with a small chain hoist, which is also used when taking the carbons out or placing them in the retorts. The interior width of the ring is about 1½ metres, while the total effective length is about 62 metres, which is divided into 32 sections. The air and flames take a horizontal direction as in other ring furnaces.

In considering the pros and cons of the two systems that have been just explained, and in determining what furnace is the most suitable for carbonising carbons in a factory where economy, quality and profit are the chief objects of attainment, the author considers that preference will always be given to the Mendheim chamber system. Because:—

(*a*) In the gas ring furnace we have seen that the air necessary for combustion circulates horizontally through the whole cross-section of the ring, and that the combustible gases generally issue from the bottom or sides of the furnace. It is evident that under such conditions a thorough mixing of the gas and air cannot take place, and this is one of the most important requirements necessary for a perfect combustion. No doubt some of the combustible gases and air escape out of that section of the ring that is in operation.—(*a*′) In the chamber system we have seen that the air and gas issue together from each opening or outlet, and thus a far more ideal mixing of these two ingredients takes place, ensuring a better combustion as the mixture gets ignited.

(*b*) Along the top of the passage, in the ring system, there must be a flow of air that simply passes through the combustion division without doing any active work, while at the same time it may absorb and carry away some of the heat there created, so that, on the whole, either a lower temperature is obtained than desired, or a greater expenditure of fuel is necessitated in order to attain the desired intensity of heat.—(*b*′) In the chamber system the flow of air can be controlled and regulated by the valves or dampers that are placed in the air passages, and a passage by which the air may escape unburned as in the ring system (does not exist) in the chamber system.

(*c*) Another fact concerning the ring furnaces, which has been verified by tests, is that the air, in becoming heated as it circulates through the hot finished divisions of the ring, gets specifically lighter than the heavy hydro-carbon gases, and thus, when it enters that part where the combustion is going on, two strata or layers are formed by the air and gas which produce only a partly mixed fuel for combustion. At the top there may be air, and at the bottom of the furnace gas, both of which may escape out of the combustion division. This means the creation of a lower temperature and a loss in fuel, while the heat from the finished divisions is uselessly taken away and absorbed by some air that serves no purpose.—(*c*′) In the chamber system of furnace it has been seen that, as air and gas flow out together through small openings, no such stratification can take place, as the conditions of egress are totally different, and thus in this system there will not be such a tendency for unburned gas to escape.

(*d*) In the ring furnace it is evident that, as the air supply is simply from one huge mouth, this air, later on as the finished parts have lost the greater part of their heat, will circulate in strata of various densities, thus producing an uneven distribution of oxygen.—(*d*′) The construction of the chamber system prevents such unequal distribution.

(*e*) Another point to be noticed in the ring furnace system is that there must be an abundance—in fact, an excess—of air which must pass the first rows of orifices from which gas flows, so that the other orifices in the back may also be supplied. It can be imagined that, as practically no regulation of air can be effected in the ring system, plenty of air must also escape by reason of what has just been said, as it is impossible to suppose that when the superfluous air passes the first rows of jets there is just sufficient oxygen left for the hind rows. In order to get combustion at these rows there must be a plenteous supply of air, some of which, it is evident, will escape. Escape of air or gas in a furnace always produces detrimental conditions.—(*e*′) In the chamber system the air flows out only in conjunction with gas, and thus no such conditions as those referred to in the ring system can obtain.

(*f*) It is also clear that when the combustion is going on in any part of the ring, as explained above under *e*, the chemical action of combustion must be somewhat weaker at the opposite end to that at which the air enters, as the dead gases resulting from the combustion going on there must pass the back flames and thus dilute and attenuate the surrounding air, thereby diminishing the chemical actions at those parts, unless a considerable superfluous quantity of air flows, of which a large portion will escape.—(*f′*) In the chamber system such a thing does not happen, as each orifice of gas has its special delivery of air.

From what has been explained it will be seen that the chamber system has many good points over the ring system when considering the subject in regard to carbon baking, while generally also a higher temperature may be raised in the chamber system than in the ring furnace. Also the fact that each chamber, when heated up, holds and retains its heat much longer than a division in the ring system enables us to feed hotter air into the combustion chamber, or to keep the air hot longer than is possible with the ring system. Practice has also shown that the horizontal flames that shoot on the retorts in the ring furnace have a great tendency to crack the latter, and it may be pointed out that a retort can only be used on the average 10 or 15 times under these conditions.

For electrode, chemical or smelting works, &c., which do not need such a large quantity of electrodes as to warrant the building of a chamber or intermittent chamber system, the Mendheim periodical furnace is no doubt the best to adopt. As such works only need from 2,000kg. to 4,000kg. of electrodes per week, they need to employ only a few men to prepare the material, so that about one day in the week is almost sufficient for squirting and forming the electrodes. In such cases it is evident that a continuous or even intermittent working of the furnace is hardly possible, and that a periodical furnace is the best suited for the purpose of carbonising.

Although there is not such an economy in the fuel in these kinds of furnaces as in the chamber system, yet a considerable portion of the waste heat is used in heating the air that feeds the combustion. But it is not possible to heat up the electrodes slowly by means of the waste heat, as is the case in the chamber system already described, because there is only one chamber in such a periodical furnace. On the whole, however, economy in fuel does not play such an important part in a small plant as in a large one. In the periodical furnace, after the electrodes have been packed and placed in the chamber, only a slow and low fire is at first started and kept up for a day or two, so that the goods will be gradually heated at the beginning; after a while the intensity of the fire is increased, until it is brought up to its highest point. Subjecting the electrodes then to such a heat for 30 to 40 hours, the fire is allowed to sink again slowly and is at last extinguished. The furnace is then allowed to cool off by partly opening the dampers that control the air canals.

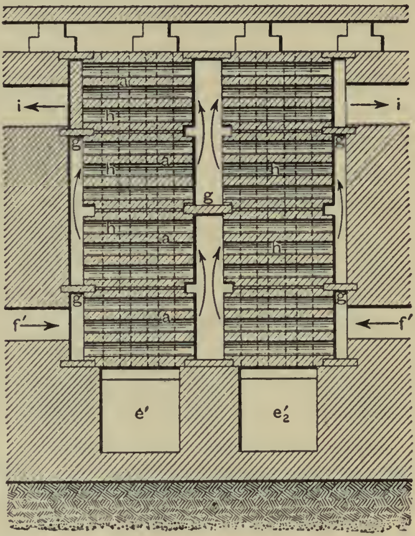


FIG. 50.—Mendheim's Continuous Regenerator. (Side view.)

The ingenious apparatus designed by Mendheim for utilising a large part of the waste heat to warm up the air necessary for the combustion going on in the furnace is shown in Figs. 50 and 51, which give two side views of this regenerator. In Fig. 54 we have a plan of the same at G, which is on a smaller scale than the other drawings, and in Fig. 53 we see the position of G with regard to the whole furnace. The generator consists of large moulded blocks, *aaa* (Figs. 50 and 51), made of fire-clay. These contain two series of passages, one set being at right angles to the other, as shown. The air flows through the one set *h h h*, while the waste heat passes through the other set *b b b*. In Fig. 50 the air enters at the passage f', and goes into the space *g*, and through the passages *h* from one block to another in zigzag fashion until it reaches the passage *i* that leads into the fire-boxes of the combustion chamber. The waste heat of combustion enters the passages *c c c*, flows through the passages *b b b*, and out into the flues e' and e'_2 that lead to the chimney. In passing through the passages *b b b* the fire-clay blocks take up a large amount of heat, which is in turn absorbed by the air that flows through the passages *h h h*, and thus a constant supply of heated air is delivered to the furnace.

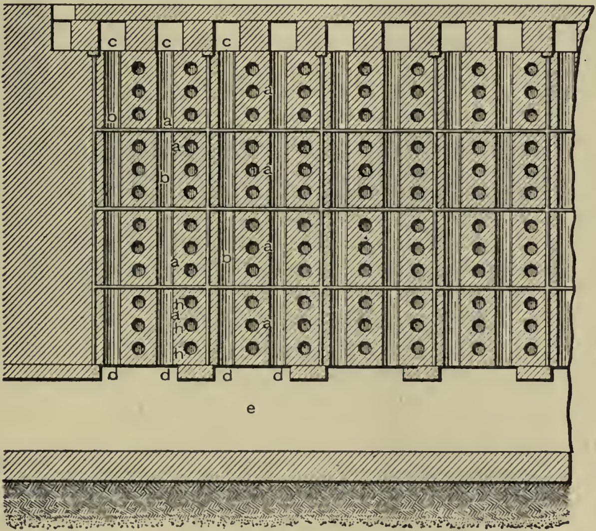


Fig. 51.—Mendheim's Continuous Regenerator. (Side view.)

In Figs. 52, 53 and 54 we have a cross-section and plans of the periodical furnace, which, as will be seen, consists of the gas generators *k*, to which fuel is supplied at k'. The gases generated flow into the fire-boxes at *l*, where they get mixed with air which enters the furnace by way of the passages $f'f'f'$

into the regenerator G, and out into the passage *i* that leads to the fire-boxes *l l*. The flames that ensue from the combustion that takes place at *l* strike upward and then turn downward, as shown by the arrows in the carbonising chamber C. It will be noticed that the fire is well distributed, as the flames divide and pass out through the numerous openings *m m m* that are in the floor of the furnace. From these openings the hot waste gases pass into the passages *c c c*, through the

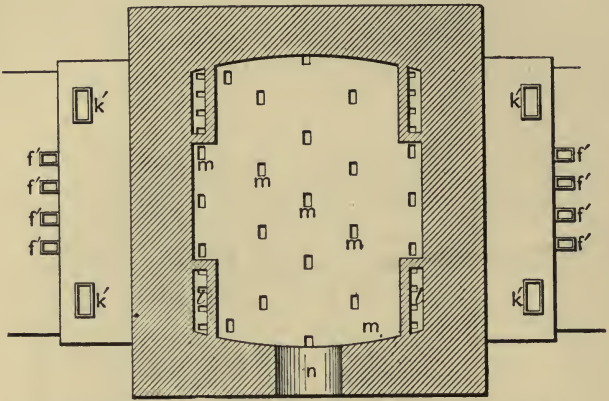


FIG. 52.—Mendheim's Periodical Half-Gas Furnace. (Plan.)

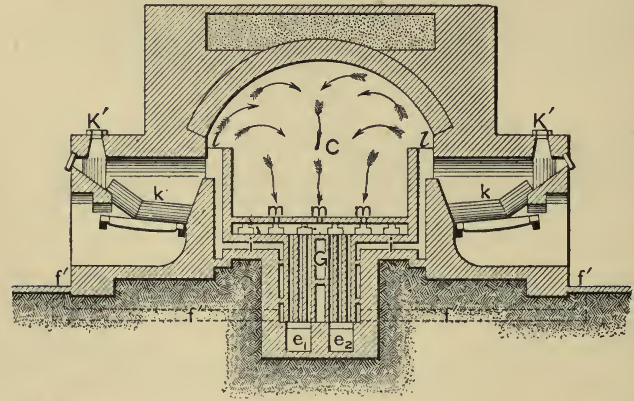


FIG. 53.—Mendheim's Periodical Half-Gas Furnace. (Cross section.)

regenerator, and out into the passages e_1 and e_2 that lead into the common flue F that is connected with the chimney. The entrance into the furnace is shown at *n*, which is filled up with fire-bricks when in operation.

In starting the furnace only a little fuel is at first supplied at *k*, so as to obtain a low fire, while the air dampers of the passages *f′f′f′* are closed. This starting of the fire is in all respects similar to that in an ordinary furnace, as the object is not to work it on the generator principle at first, so that a low fire can be obtained, by means of which the articles in the furnace can be slowly heated up. The intensity of the fire is gradually increased until the electrodes, or rather the boxes in which they are packed, are at a red heat. After this stage has been reached fuel is added slowly until all signs of flames in the generators at *k* have disappeared. At this point of the operation we have the transition from the ordinary furnace into the gas generator, for when the flames are gone the gas begins to be produced, and it is then necessary to open the dampers of the air canals *f′f′f′*, so that air can be supplied to the gases as they issue into the fire boxes *l*, where the combustion takes place. For the above reason these furnaces are often called "periodical furnaces with half-gas firing," as they are started at first with an ordinary fire and later on change to the generator principle.

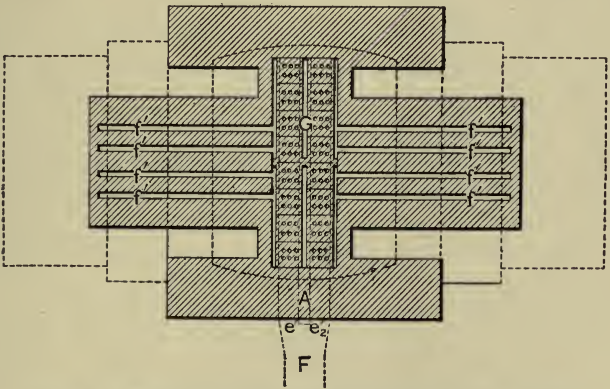


Fig. 54.—Mendheim's Periodical Half-Gas Furnace. (Plan.)

After the electrodes, or carbons, have been subjected to the highest heat for a sufficient length of time, the fuel is allowed to sink again, so that ultimately the furnace works again with an ordinary fire, which is also allowed to sink in intensity from time to time until at last it is extinguished. The furnace is then allowed to cool off slowly by means of the dampers that control the air passages. The whole operation of firing, &c., takes about four to five days, and we can also reckon about two days for cooling, so that in all a week is taken up in carbonising one batch of electrodes.

From what has been explained it will be seen that these periodical half-gas furnaces are especially well adapted for private concerns that wish to make their own electrodes, and do not need more in a week than what one furnace can bake. Large heavy electrodes can be thoroughly carbonised, as they must be subjected for a longer time to a higher heat than ordinary carbons, which have on the whole a much smaller mass compared to some of the electrodes used in electrical smelting works. It takes time for the heat to penetrate through large masses of carbon, and, as we have seen, there is always a constant supply of hot air that materially helps to produce a very great and constant intensity of heat in the combustion chamber.

We have seen that in the chamber system the air supplied receives its heat from those chambers in which the carbons have already been carbonised, and it is evident that the temperature of those chambers gradually sinks as the heat is taken away by the air in passing through them, and thus also the temperature of the air, until a new finished chamber is again added to the series. In the Mendheim periodical furnace the air always retains a constant high temperature when the furnace is in full operation.

It is, as will be readily seen, a fallacy for a carbon manufacturer who desires to work on a commercial scale, and to produce large quantities of finished goods, to employ the periodical type of furnace instead of the chamber or ring systems. In such large works economy of fuel is an important item, and we have also the important condition of the gradual heating and cooling of the carbons. The latter cannot be so methodically effected in the periodical furnaces as in the chamber or ring system, for we have seen that these conditions depend upon the management of the fire in the former type of furnace, while in the chamber or ring system the proper condition is brought about by the waste heat or air that is permitted to circulate from one chamber to another, thus effecting a systematic and gradual heating or cooling, quite independent of the workman handling the furnace.

It is well known that carbon rods are far more apt to warp than thick heavy electrodes, and thus it is necessary to use a finer apparatus or furnace to bake the former than the latter. Another fact not to be forgotten is that the chamber system works continuously, and that carbons are finished every day, while the cost of such a system is much less than an equivalent number of periodical furnaces that can carbonise the same amount of carbons. There is also much less labour in handling a chamber system than a number of periodical furnaces, so that it is inconceivable, when considering all the advantages the chamber system possesses, why some carbon manufacturers should still employ the periodical furnace, notwithstanding the fact that the best carbon makers in Germany have long ago discarded its use. We may repeat that there is no objection to the employment of the periodical furnace when only a limited number of electrodes are required to be carbonised, but when a commercial undertaking manufactures carbons which they wish to sell to the public, they will certainly find that it is a very expensive method to use the periodical type of furnace, and they will then understand why their competitors can afford to undersell them with a better brand of goods.

As has already been mentioned, the Aluminium Industrie Actiengesellschaft, in Neuhausen, manufacture their own electrodes, and as they need a large number, they employ a continuous type of furnace which the author has not yet explained. This system consists of a stationary fire and movable hearths. The author was informed, while in Switzerland some time ago, that the furnace was especially constructed for the Aluminium Company by Menheim, but he was unable to obtain any drawings or data. The system of furnace is, however, not new, and Mr. Rogler informs the author that one, designed by Bock, has been in operation for years at the large pottery works of Fikentscher, in Zwickau, Saxony. Other similar designs have been constructed by Siemens-Hess and also by Pernot, who constructed a furnace in which the bed is mounted on wheels so as to be moved in and out of the fire. The latter type is used in the manufacture of steel.

Some time ago the author designed a similar furnace for a firm that intended to build a carbon and electrode factory, but as the duty on carbons was increased in the United States the matter was dropped. Figs. 55, 56 and 57 represent the author's design. Here G indicates the main gas passage connected with the generators. The latter are best built on the side of the furnace, as this gives a minimum length for the passage—an advantage over the many metres necessary in the other continuous systems, as the gas arrives much hotter in the combustion chamber; for we have already seen that the temperature of the gas can sink as much as 50°C. to 75°C. per metre. From the passage G the gas can be led to either side of the furnace by way of *g*, *g′* or *g″* as shown, and can be permitted to pass into the reservoir chambers R R by simply

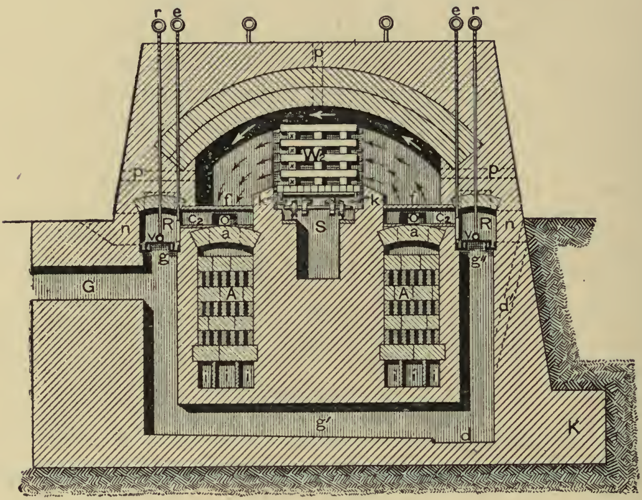


FIG. 55.—Jehl's Continuous Furnace with Tunnel and Regenerator. (Cross section view.)

lifting the valves *v* or *v′*, which are actuated by means of the rods *r r*. These rods can be held in any position by inserting pins in one of the holes at their upper ends. The section *d* in the passage *g′* acts as a drain for any condensed matter that may settle, and which can be pumped up by inserting a pipe into the hole *d′* at the side of the furnace, as shown in Fig. 55.

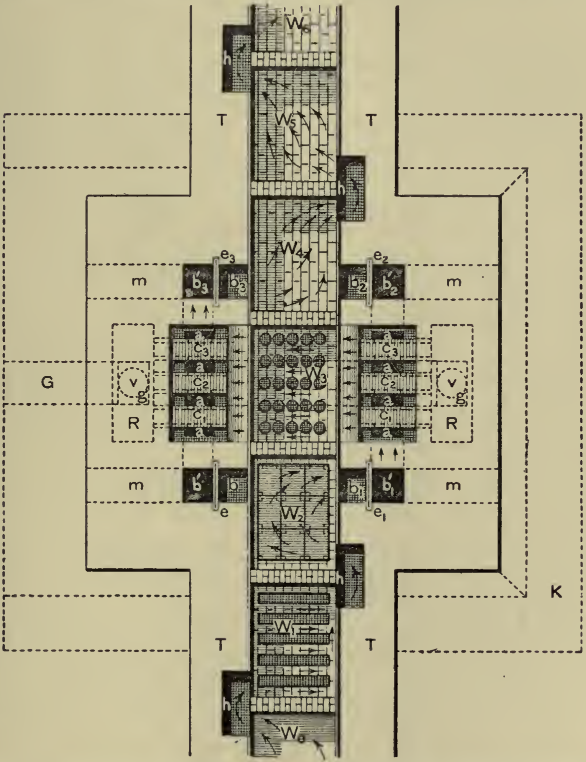


Fig. 56.—Jehl's Continuous Furnace with Tunnel and Regenerator. (Plan.)

This opening is, of course, always closed up when not in use, as otherwise gas would escape. It is hardly probable, however, that any tarry matter will condense, as the gases only travel a short distance and are too hot to allow condensation. When a valve at R is raised, the gases enter the reservoir chamber which communicates with the branch passages c_1, c_2, c_3

that lead into the fire boxes *ff*. The flow of gas into each of these branches can be regulated or stopped by means of dampers that are connected to the rods *ee*.

As seen from the plan, there are three such branches, c_1 c_2 c_3, that lead from the reservoir chambers R into each fire box, while the gas flows out horizontally in the middle of the fire box at openings *oo* on each side of the branch passages, as shown in the cross section Fig. 55. The air that is necessary for combustion enters at *b* or b_1, according to which side of the furnace the gas is turned on, and from there it passes into the passage b' or b'_1 that leads into the regenerator A at *iii*, Fig. 55, where it gets heated up to a high degree and then passes out at the openings *aaaa* in the fire box *f*, striking the gases at right angles, and thus becoming well mixed. The flames that result from the combustion have plenty of room over the fire box to expand, according to Siemens' theory, and then take an even and well-distributed path as shown by the arrows.

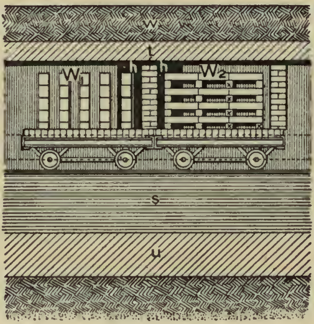


FIG. 57.—Jehl's Continuous Furnace with Tunnel and Regenerator. (Longitudinal section of tunnel.)

In Fig. 56 the passages $b_3\,b'_3$ and $b_2\,b'_2$ serve to conduct the burnt gases away, while $e\,e_1\,e_2\,e_3$ are dampers by means of which the passage can either be closed or regulated; *mmmm* are entrances which permit access to the canals $b\,b_1\,b_2\,b_3$ and the generators, but which are well sealed up with fire bricks when the furnace is in order. In Fig. 55 *nn* are similar entrances that lead into the reservoir chambers when inspection is necessary, but are also well sealed up when the furnace is working. The peep-holes are shown at *ppp*, and should be covered with mica so as to prevent cold air from entering.

On both sides of the furnace is a tunnel, T T T T (Fig. 56), a portion of the longitudinal section of which is shown in Fig. 57. Here *t* is the roof on which earth *w* is banked so as to prevent the heat from dissipating, *u* is the foundation, and through the centre runs a passage, *s*, the cross section of which is shown in Fig. 55. On steps of this passage rails are placed, on which waggons $W_1 W_2$ run as shown in all the figures. The waggons should be constructed of wrought iron, while on the sides a projecting strip of iron dips into a U-formed rut that is filled with sand, as shown in Fig. 55 at *k*. This cuts off the heat and prevents it from getting into the lower passage *s*, and thus the lower part of the waggons are protected. It is better, however, to have the U-formed rut attached to the waggons and to have the straight strip fixed in the wall of the tunnel, as then the rut can always be filled with fresh sand when a waggon is placed into the tunnel. In the waggons a layer of sand is placed, on which a good bed of the best fire bricks is laid, while at one end of each waggon a wall is built, as shown in Fig. 57, covering the cross section of the tunnel except for a reasonable clearance.

By this means we obtain a sort of chamber system, the number of chambers depending upon the number of waggons or the length of the tunnel, while communication between each compartment is effected by passages *h* (shown in Figs. 56 and 57) built in the sides of the tunnel. It will be seen from what has so far been explained that this system offers the same advantages as those given by the other continuous systems, and that the waste heat is just as economically employed, for here, too, the heat contained in the retorts, &c., that have been finished is utilised for warming up the air that is used for combustion, while the heat of the gases that result from combustion is used in warming up a regenerator and those waggons that contain carbons or electrodes not yet baked.

In order to render the working of the authors's furnace system clearer, the following example may be taken :—We will suppose that waggon W_3, Fig. 56, is in operation, and that

$W_4 W_5 W_6$ are waggons that contain carbons that have not yet been baked, while those in waggons $W_2 W_1$ have already been carbonised. The valves and dampers that control the gas and air passages at $g\,e\,e_2$ are closed, while those at $g''\,e_1\,e_3$ are opened. The air entering the tunnel on the side where the waggons $W_0 W_1 W_2$ are situated takes up the heat contained in these waggons as it circulates from one compartment to another by way of the passages h, until it arrives at b_1, where it enters and passes into the canal b'_1 that leads into the right hand generator A (shown in Fig. 55), where it is heated up to a very high temperature, and then issues out at the openings $a\,a$, mixing well with the combustible gases that also issue out over these openings, so that a very good combustion takes place, the flames of which strike the retorts or fire-clay cases, pass between them, and leave at the other openings on the opposite side, as shown by the arrows in Fig. 55. These hot gases in passing the openings $a\,a$, circulate through the generator A on the left-hand side, which received a great part of the heat, while the rest is taken up in the waggons $W_4 W_5 W_6$, as the heat in leaving the generator enters the canal b'_3 and out at b_3 into the compartment W_4, &c., as shown by the arrows in Fig. 56. After the fire has been working for a few hours on one side, its direction is reversed by closing up the valves and dampers that are opened and opening those that are closed. By this means the retorts, &c., are evenly heated, and are at all parts subjected to an even intensity of heat, which is so important in carbonising. When the contents of a waggon have been finished, the whole series are pushed one space further, while at one end of the tunnel a waggon is taken away and at the other end one is added, the rails being connected with a turntable at each end, so that the waggons can be pushed into the packing and receiving departments.

The manner in which a waggon is placed in the tunnel without interrupting the draught is best understood from the diagram shown in Fig. 58. Here T_1 represents that part of the tunnel that contains the waggons in which the goods have already been carbonised, and, as seen, its end is open so as to permit the air to enter that is fed to the fire in the furnace F. T_2 is the part of the tunnel that contains the unfinished carbons or electrodes, and the arrow shows the direction in which the waggons move. The rails are indicated by *r*, and the turn tables are placed at *t*. G shows the positions of the generators, and C that of the chimney. At *d* there is a sort of damper or sliding door made of sheet iron, which, when slid into the tunnel, covers its whole cross-section, and at *e* there is a ordinary tight-fitting door, also of sheet iron.

At P there is an apparatus which may either be a sort of large, long screw or a suitable hydraulic machine that can be used from time to time to push the train of waggons that are in the tunnel. When the contents of a waggon have been carbonised in the furnace F, the apparatus P is so actuated that the waggons in the tunnel are moved one space further, which act delivers a finished waggon at the end T_1, while at the other end room is made for a waggon to be added. A waggon that has been newly packed with fresh goods is then pushed from the packing department on to the turn table at the T_2 end of the tunnel, and at the same time the sliding door *d* is pushed in so that it cuts off the part *c*. The door *e* is then opened and the waggon pushed in, after which *e* is closed again and the sliding door drawn back. By this simple means waggons can be moved into the tunnel without interrupting the draught, &c.

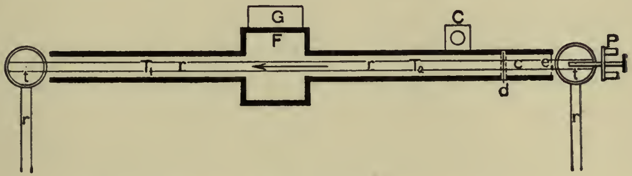


Fig. 58.—Diagram of Jehl's Tunnel System of Furnace.

The advantages the writer claims for his furnace system for the carbon industry are the following:—

There is a large economy in fuel while the greatest possible effect is obtained. The heat contained in the finished articles is taken up by the air used for combustion, which cools them gradually. The heated gases as they leave the furnace heat up a regenerator with a large surface, and after leaving the latter the hot gases slowly and gradually heat up the fresh carbons.

There is a decided advantage in not having a large network of passages and flues, as is necessary in the chamber system, &c., and thus the gas from the generator arrives in the furnace very hot, whereas in those systems where it has to travel long distances it cools down considerably, which means less economy in fuel. In fact the absence of networks of passages, complicated systems of chambers, &c., lessens the cost of the building and maintenance of the author's system. In the tunnel system there is only one set of valves and dampers, while in the chamber or ring system there is a set for every chamber or division, so that the chances of gas escaping is reduced to a minimum in the author's system, while the handling gives less work than in other systems. Also, there being but one chamber in which combustion takes place, it can always be maintained at a high temperature; in the other systems the chambers must first be heated up.

The advantage, in a continuous system, of having a regenerator like that shown in Fig. 55 gives us a means with which the fire can be kept up for any length of time and always at a high intensity, while the direction can be reversed from time to time, so that the action of the flames and heat will produce an even and well-distributed effect on both sides of the retorts and cases that contain the carbons. This cannot be produced in the other systems. This method of changing the direction of the fire from time to time always furnishes us with a well-heated regenerator, and is much used in steel manufacture, where only a very high intensity of heat can be used; so that, in adapting the same for carbonising carbons and electrodes, the more ideal requirements can be obtained. Large electrodes need a very high intensity of heat for a considerable length of time, so that the heat can penetrate into the interior of the carbon mass. This takes time, as carbon is a very bad conductor.

The advantages in handling the carbons, &c., in the author's system save time and labour, as the carbons and electrodes can be packed in the packing department on the waggons direct, and the finished goods can be delivered into the receiving department. In the other systems the carbons must be packed, be then brought to the furnace, and then placed in the chambers; the entrances of the latter must always be sealed up with fire-bricks, which are removed again when the chamber is emptied. All this extra work is not necessary in the system described in Figs. 55 to 58. Of course in this system we have the expense of the waggons, but their cost is more than balanced by the lower cost in building a simple tunnel—one furnace with hardly any length of passages.

A convenient and cheap method of packing electrodes, &c., on the waggons can be effected by means of pieces made of the best fire-clay (chamotte), as shown in Fig. 59. Here pieces similar to *a* serve for the ends, and pieces like *b* are placed between the ends of a trough that is constructed on the waggon. In the waggon W_2 (Figs. 55 to 57) this method of packing is shown. Here *x* indicates fire-bricks that are laid at even lengths, so as to support the trough, while at the same time passages are formed through which the flames and heat can pass. On these fire-bricks pieces similar to those shown in Fig. 59 are laid, their sides being smeared up smooth with fire-clay in order to keep the contents of the trough so formed from burning. In the trough a few fire-bricks are also placed to support the cover, which consists simply of fire-clay slabs. A good bed of carbon dust is placed in the trough, on which the electrodes, &c., are laid, and they are then covered up again with carbon dust, on which the slabs are then placed. In a similar manner four or five such troughs are laid on a waggon, so that there are many passages (as shown in the Figs. 55 to 57), through which the flames and heat can play, and the electrodes are evenly carbonised. It will be seen that such a method of making large troughs is much cheaper than employing troughs made of one piece, for when such a trough breaks it is of no value while when a piece like that shown in Fig. 59 breaks it can be replaced at little cost. It is also possible to

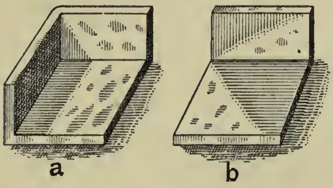


FIG. 59.—Forms made of Fire-clay for packing Carbons and Electrodes.

have such pieces made thinner than can safely be used when whole troughs are made.

In Fig. 60 we have a view of a trough made in one piece, as is sometimes used in carbon factories, and to which a cover is provided. These troughs often break, and especially at or near the bottom, as this part is generally made much thicker than the sides.

The author proposes to have such troughs made without bottoms, which will cost much less, while at the same time they will stand the action of the fire better than those with bottoms. The first trough is laid in the waggon and filled with sand; on the top of this another bottomless trough is placed and packed with electrodes; then another, and so on, as shown in Figs. 56 and 57 at waggon W_1. This method affords also ample passage for the heat and flames. Instead of using such a form for the lower row, fire bricks can be laid on which a slab rests, on which slab the troughs can be placed, while the top one is, of course, also covered with fire-clay slabs. It will be seen that many good ways can be found by which the carbons can be easily packed on the waggons. In Fig. 61 *a* represents another fire-clay box, used sometimes for brushes, &c. These boxes can also be made bottomless, so that they can be placed to fit one upon another, so as to make a long retort. Instead of square forms, round ones are also often used. *b* represents the retorts mostly used by carbon manufacturers for electric light carbons, and it will be seen that if such retorts are constructed from two or three pieces they will be cheaper than when made in one piece. These large retorts often break, and their cost is a considerable item in the expenses of a carbon factory.

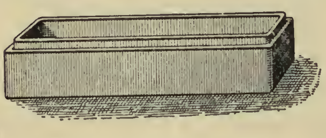


FIG. 60.—Fire-clay Trough.

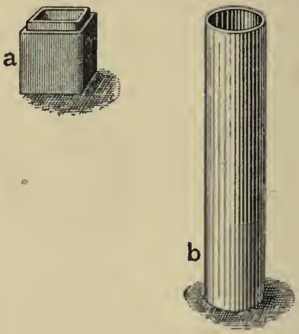


FIG. 61.—Fire-clay Box and Retort.

CHAPTER IX.

ESTIMATION OF HIGH TEMPERATURE.

Among carbon manufacturers, the ordinary parlance, when referring to the temperature at which they bake their carbons, will generally be found similar to that used in the pottery industry—that is, as designated by Prof. Seger's pyramids. It is a well-known fact to pottery manufacturers that it was formerly a very difficult thing for them to estimate in a practical way the temperature at which they had to bake their goods. To use pyrometers, no matter of what design, generally required some skilled attention, while at the same time the readings of such instruments were often misleading.

At the request of a well-known "chamotte" manufacturer in Germany, Prof. Seger made a series of exhaustive experiments to determine the different points of fusion of certain mixtures of pure silicates, &c., which he moulded into the shape of small blunted pyramids. In fact, the Seger pyramids represent a series of systematic mixtures, each of which have a different point of fusion, varying 20°C. to 30°C. from one another. Thus one set of the Seger pyramids that is numbered from 0·22 to 0·10 can be used to estimate temperature that lies between 590°C. to 950°C. respectively, there being a difference of about 30deg. between each successive number in regard to its point of fusion. Another set, numbered from 0·9 to 1·0, is used for temperatures varying from 970°C. to 1,130°C., while each succcessive number's point of fusion varies by 20deg. A third set, 1 to 36, is used for temperatures between 1,150°C. and 1850°C. respectively, each successive number's point of fusion varying also by 20deg. Thus, by means of the 58 pyramids, any temperature between dull red and the melting point of platinum can be estimated. When a carbon manufacturer, therefore, says he uses a No. 17 or 18 Seger pyramid in his Mendheim furnace, he means that he bakes his carbons at an estimated temperature of about 1470°C. or 1490°C. respectively.

It must be understood that this mode of measuring temperature is not to be taken as scientifically correct, but in practice it has been found to suit all requirements, and the estimation of heat obtained by such means has enabled the pottery industry (as well as the carbon trade) to burn or bake their goods with a precision heretofore unknown. The following table* gives the numbers, chemical composition and the estimated temperature at which the pyramids most commonly used by carbon makers fuse, or rather fall over, when subjected to a certain heat :—

Pyramid number.	Chemical composition.	Estimated temp. Degs. Centigrade.
10	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}1{\cdot}0\ Al_2O_3\ 10\ SiO_2$	1,330
11	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}1{\cdot}2\ Al_2O_3\ 12\ SiO_2$	1,350
12	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}1{\cdot}4\ Al_2O_3\ 14\ SiO_2$	1,370
13	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}1{\cdot}6\ Al_2O_3\ 16\ SiO_2$	1,390
14	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}1{\cdot}8\ Al_2O_3\ 18\ SiO_2$	1,410
15	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}2{\cdot}1\ Al_2O_3\ 21\ SiO_2$	1,430
16	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}2{\cdot}4\ Al_2O_3\ 24\ SiO_2$	1,450
17	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}2{\cdot}7\ Al_2O_3\ 27\ SiO_2$	1,470
18	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}3{\cdot}1\ Al_2O_3\ 31\ SiO_2$	1,490
19	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}3{\cdot}5\ Al_2O_3\ 35\ SiO_2$	1,510
20	$\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}3{\cdot}9\ Al_2O_3\ 39\ SiO_2$	1,530

It is usual to place the pyramids (two or three successive numbers) in two different parts of the furnace so as to be able to get a good idea of how the heat is distributed, and not to

---

* For a detailed account of Prof. Seger's pyramids, *see* pamphlet published by the *Thonindustrie Zeitung* (Berlin).

turn off the gas until all parts of the chamber have an even temperature. It is, of course, understood that the pyramids should be protected from the direct action of the flames, as otherwise erroneous results are obtained.

The best way to place the pyramids in the furnace is to protect them by some fire-bricks, as shown in Fig. 62, and at the same time they must be so placed that they can be seen from the peep-holes of the furnace. These peep-holes are generally covered with mica, to prevent the air from getting in when observations are made. When not in use these holes are covered with fire-bricks. In using three successive numbers of the pyramids at a time for observation we have a convenient way of noticing the rise in heat, and Fig. 63 will serve to show how the estimation is approximately judged and fixed. Here we have the three pyramids—17, 18, 19—that have already been subjected to the action of a furnace. We see that 17 is fused down, and conclude that the temperature that existed must have been higher than 1,470deg. Pyramid 18 is pretty well bent over, and we can thus estimate that the

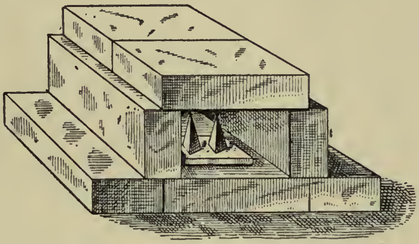


Fig. 62.—Method of Protecting the Pyramids.

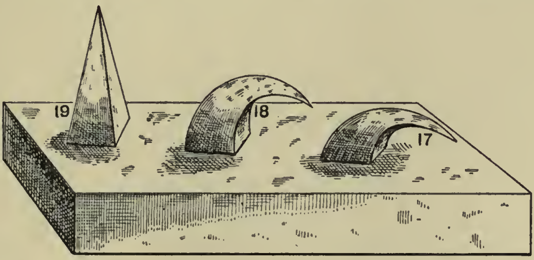


Fig. 63.—Seger Pyramids in the Furnace.

intensity of the heat must have been very near to 1,490deg. That the temperature did not reach as high as 1,510deg. is proved by the fact that pyramid 19 is still straight.

It will be seen that the whole method of observation is a very simple one, and that any ordinary workman can be entrusted with it. The pyramids should always be placed in the same place in the furnace, so as to always get the same relative results. When the pyramids have once been used they are not good for a second time, and new ones must always be placed in the furnace with each charge. As they are very cheap, this is a matter of no importance. The pyramids can be had at the laboratory of Dr. Seger, in Berlin, at 4s. 6d. per 100. To prevent the pyramids from falling over, it is usual to use a little fire-clay to attach them at their bases to the fire-brick.

CHAPTER X.

GAS ANALYSIS.

In these days of close competition, it is the object of every manufacturer to economise in every possible direction, and especially in obtaining the best working efficiency of his plant. The conversion of fuel into gases by means of gas generators and the burning of the combustible gases in the furnace demands some control or check, by which the manufacturer may determine the best conditions of working, and thus be able to secure the most favourable results. One of the best methods to determine such facts is by analysing the gases that are produced by the gas generator and those that result from combustion in the furnace. By such means the manufacturer can find out which fuel give him the best results, and what handling the generator and furnace require. As has already been stated, the object of the gas generator is principally to convert the fuel into carbonic oxide gas, while the production of carbonic acid gas can only be considered as a loss. On the other hand, all the combustible gases should be burned in the furnace, and the gases issuing into the chimney should only consist of dead gases—that is, such gases as carbonic acid, nitrogen, &c., and if carbonic oxide gas escapes unburned it is a loss. Thus, in order to obtain the best conditions in the generator and furnace, we must know the nature of the actions going on. This knowledge can be practically obtained by analysing the gases that are produced, and then regulating the air supply to suit the requirements. As has been explained, the conditions in both generator and furnace depend greatly upon the amount of air supplied, so that a proper adjustment of the dampers, both those controlling the air and the gas passages, is of vital importance, in order to obtain the best results with a given amount of fuel.

Among the numerous types of apparatus designed for analysing gases no doubt the simplest and most efficient for all practical purposes is the gas burette constructed by Dr. Bunte and shown in Fig. 64. As seen, the burette is simple, cheap and easily handled, so that any workman after a little training can make the tests himself. The Bunte burette consists of a graduated glass cylinder that is enlarged at its upper end, the whole having a capacity of about 100 cubic cm. At its upper end there is a three-way cock *a*, over which we have a sort of test tube receptacle *c*, while at its lower end there is a simple cock *b*, as shown.

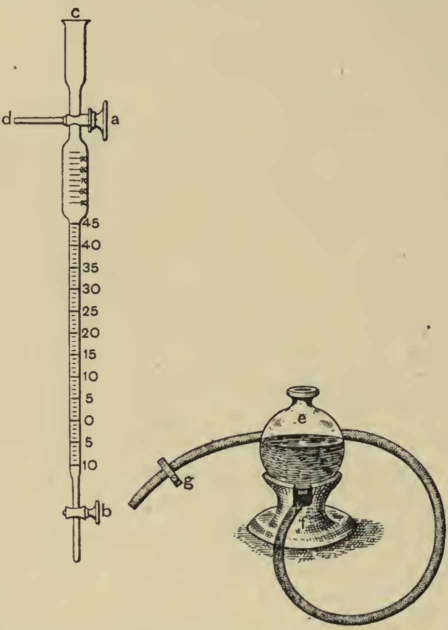


Fig. 64.—Dr. Bunte's Burette for Gas Analysis.

When beginning a test, the burette is filled with water, which can best be done by connecting its lower end with a rubber tube that is connected to a bottle containing water, a convenient form of which is shown in Fig. 64. Here *e* is a round sort of bottle having a projecting neck at its bottom end, to which the tube is fixed, while the whole rests when not in use on a wooden pedestal, *f*, in which there is a slit for the tube. At *g* we have a clamp that prevents the water from flowing out when the bottle is not in use. The cock *a* is then so turned that the air can escape as the water bottle is raised. When the burette is filled, and the water level reaches up to the cock *a*, the cock *b* is turned so as to cut off the water passage, while a rubber tube is connected at the end of the three-way cock *a* at *d*, and this tube is connected with the gas supply that is to be tested. It is well, first, to let some of the gas escape out of the rubber tube, so as to be sure that it contains no air. After the gas tube is connected to the burette, the cock at *b* is opened again, and the water is allowed to sink by lowering the bottle. By these means the gas is sucked into the burette, and when the same has reached about the eighth graduated space below 0, the three-way cock *a* is turned so as to cut off the gas passage.

We must now regulate our gas in the burette so as to have about 100 cubic cm., which should be at the ordinary atmospheric pressure. This is done by raising the water bottle slowly, so that its level and that of the water in the burette are equal, and reach the 0 point on the scale, while the surplus gas is allowed to escape by turning the cock *a* a little, after which it is closed again. The water bottle is then lowered again, so that all the water in the burette sinks below the stop-cock *b*, after which this cock is turned and the tubing can be removed.

The burette is now free for handling, and contains 100 cubic cm. of gases that are to be analysed, The lower end of the burette is now dipped into a beaker that contains the absorption fluid, which may at first be either a solution of sodium or potassium hydrate ($2NaAOH + 7H_2O$ or $2KHO + 7H_2O$). This fluid absorbs all the carbonic acid gas there is in the burette, and as soon as the cock *b* is opened, some of the fluid ascends, after which the cock is closed again, and the burette is gently agitated, so that the absorption fluid has ample opportunity to absorb all the carbonic acid gas. After two or three minutes we shall find that the volume of the gases has decreased, and the loss in volume is best measured by filling the tube at *c* with water, and allowing it to flow into the burette by turning the cock at *a*. Only so much water will flow out of the tube *c* into the burette, as there has been a loss in volume of the gases; therefore the water that flows into the burette is a measure of the volume of carbonic acid gas that has been absorbed.

However, before reading off this loss in volume it is best first to drive out the absorption fluid, and this is done by allowing water to flow into the burette from *c* by opening the cocks at *a* and *b*, care being taken that the tube *c* is always full and that there is also some water at the lower end of the burette, so that no gas can escape. By this means we give the burette a good washing, and can free it from any absorption fluid. After this has been done, the cock at *b* is turned, and we can now read off the loss in volume by allowing as much water as will flow into the burette from the tube *c* to enter. The amount of water contained in the burette from 0 represents, therefore, the volume of carbonic acid gas our mixture contained. As is evident from what has been explained, the reading gives the volume per cent. In the same manner as has been explained above we proceed with the other absorption fluids in determining the volumes of carbonic oxide gas or oxygen that our mixture contains, and it is sufficient for all practical purposes to simply determine the volumes of the three gases mentioned.

The absorption fluid used for determining the carbonic oxide gas is generally a solution made by taking 250 grammes of ammonium chloride (NH_4Cl), 200 grammes of cuprous chloride (Cu_2Cl_2), and about 750 cubic cm. of water. The fluid used for determining the oxygen can be a solution of 25 grammes of pyrogallic acid ($HC_6H_5O_3$) with 50 grammes of a solution of sodium or potassium hydrate.

It may be well to have a small pipe connected permanently with the generator and another with the chimney, so that the gases can easily be procured when wanted, and can be sucked by means of a Sprengel water-pump acting as an injector.

CHAPTER XI.

ESTIMATE OF THE CAPITAL EXPENDITURE, &c., NECESSARY FOR BUILDING A CARBON FACTORY.

It will, no doubt, prove interesting to many to obtain an approximate idea of the cost of producing carbons on commercial lines, and at the same time an estimate of how much capital is necessary to build a medium-sized carbon factory. In the following estimate the author has taken the prices and figures involved in such calculations, so as to suit the conditions that exist in Austria or Hungary, while at the same time he has taken liberal margins in order to be on the safe side. The figures are given in sterling, in United States dollars, in francs and in florins. As has already been shown, the prices of raw materials used in carbon manufacture are as follows per 100 kilo. (220lbs.) :—

Table A.

——	£ s. d.	$ cts.	Florins.*	Francs.
Lampblack or soot ……	1 6 7	6.40	16.00	32.00
Gas retort carbon ……	0 8 4	2.00	5.00	10.00
Petroleum coke ………	0 6 8	1.60	4.00	8.00
Tar ……………………	0 6 8	1.60	4.00	8.00
Waterglass ……………	1 13 4	8.00	20.00	40.00

* The florin is taken at 1s. 8d., 40 cents., or 2fr.; the dollar at 50d., 3fl., or 5fr.; the franc at 10d., ·50fl., or 20 cents. The francs rate will serve for calculations into pesetas and lire, subject, of course, to the fluctuations of exchange.

It has also been shown that carbon mixtures of different grades contain about the following proportions:—

Table B.

—	Lamp-black.	Gas retort or petroleum coke.	Tar.	Plumbago.
	%	%	%	%
High grade mixture	80	...	20	...
Second ditto	50	30	20	...
Third ditto	30	50	20	...
Common ditto	...	80	20	...
Carbon brushes	...	65-70	20	10-1

The amount of tar taken and used in practice is much nearer 30·33 per cent. than 20 per cent., but the writer will use the latter figure in his calculations so as to be on the sure side, while the cost of waterglass can be discarded, as the quantity used is very small, and is only employed for cored carbons. Its cost is, therefore, more than covered by the smaller percentage of tar and higher percentage of lampblack taken.

From the data we have here at hand we find that the cost of the raw mixtures used for carbons are about the following:—

Table C.—*Value of Raw Mixtures per kilogramme (2·2lbs.)*

—	£	s.	d.	$ cts.	Florins.	Francs.
High grade mixture	0	0	2·72	0.5·44	0.136	0.272
Second ditto	0	0	2·06	0.4·1	0.103	0.206
Third ditto	0	0	1·6	0.3·2	0,081	0.162
Gas retort ditto	0	0	0·96	0.1·9	0.048	0.096
Petroleum coke ditto	0	0	0·8	0.1·6	0.040	0.080

To allow for a liberal margin the author will use the following figures in all his calculations:—

Table D.

—	£	s.	d.	$ cts.	Florins.	Francs.
High grade mixture	0	0	2·8	0.5·6	0.14	0.28
Second ditto	0	0	2·2	0.4·4	0.11	0.22
Third ditto	0	0	1·8	0.3·6	0.09	0.18
Common ditto	0	0	1·0	0.2·0	0.05	0.10

The next table shows the results obtained from actual measurement of hard and soft carbons :—

Table E.

Diameter in mm.	Section in sq. mm.	Weight in grammes per metre.	
8	50	55	soft solid
9	64	75	soft cored
10	79	105	hard solid
11	95	115	soft cored
12	113	140	soft solid
13	133	195	hard cored
14	154	190	soft solid
15	176	240	soft solid
16	201	205	soft cored
20	314	375	soft cored
	1,379	1,695	

From these figures we see that the specific weights or density of electric light carbons vary from 1·10 to 1·40, and that the mean would be about 1,695 ÷ 1,379 = 1·23. We will, however take the density as being 1·30, which gives us again a margin, and calculate the weights and prices of the raw material used per 3,280ft. (1,000 metres). (See Table F.) It will be observed that these calculations are based on the Continental units, and that the same have been converted into values of English and American denominations. The author desires especially to point out that the weights given in the above table are considerably higher than those obtained from actual measurements—in fact, from 20 to 30 per cent. more, so that we have a safe margin in the subsequent calculations.

From the price lists of different European carbon makers the author has taken the prices which were the lowest, and from these he has taken off a discount of 40 per cent, which is in excess of the discount given to the most favoured customers. The particular manufacturer whose prices have been taken gives 35 per cent. discount to his best customers, so that in taking 40 per cent. the author feels he has provided a liberal margin. By means of such data Table G is calculated. Column (3) represents the selling price of carbons as already stated, the figures of which are taken from the price list where 40 per cent. discount was allowed. It will be seen, therefore, that these figures are under no circumstances taken too high,

Table F.

Diameter in		Weight per 3,280ft. = 1,000 metres in		Value of the various grade mixtures contained in 3,280ft. (1,000 metres).																							
				@ 2·8d. = 5.6cts. = 0.14fls. = 0.28fr. per 2·2lbs. = 1 kilo.						@ 2·2d. = 4.4cts. = 0.11fls. = 0.22fr. per 2·2lbs. = 1 kilo.						@ 1·8d. = 3.6cts. = 0.9fls. 0.18 = fr. per 2·2lbs. = 1 kilo.						@ 1d. = 2cts. = 0.05fls. 0.10 = fr. per 2·2lbs. = 1 kilo.					
ins.	m/m	lbs.	kilos.	£	s.	d.	$ cts.	fls.	fr.	£	s.	d.	$ cts.	fls.	fr.	£	s.	d.	$ cts.	fls.	fr.	£	s.	d.	$ cts.	fls.	fr.
$\frac{5}{16}$	8	143·0	65	0	15	2	3.64	9.10	18.20	0	11	11	2.86	7.15	14.30	0	9	9	2.34	5·85	11.70	0	5	5	1·30	3.25	6.50
$\frac{11}{32}$	9	182·6	83	0	19	4	4.64	11.62	23.24	0	15	2	3.65	9.13	18.26	0	12	5	2.98	7·47	14.94	0	6	11	1.66	4.15	8.30
$\frac{13}{32}$	10	226·6	103	1	4	0	5.76	14.42	28.84	0	18	10	4.52	11.33	22.66	0	15	5	3.70	9·27	18.54	0	8	7	2.06	5.15	10.30
$\frac{7}{16}$	11	272·8	124	1	8	11	6.94	17.36	34.72	1	2	9	5.46	13.64	27.28	0	18	7	4.46	11.16	22.32	0	10	4	2.48	6.20	12.40
$\frac{15}{32}$	12	323·4	147	1	14	4	8.24	20.60	41.20	1	6	11	6.46	16.17	32.34	1	2	0½	5.25	13.23	26.46	0	12	3	2.94	7.35	14.70
$\frac{1}{2}$	13	380·6	173	2	0	4	9.68	24.22	48.44	1	11	8	7.60	19.03	38.06	1	5	11	6.22	15.57	31.14	0	14	5	3.46	8.65	17.30
$\frac{9}{16}$	14	440·0	200	2	6	8	11.20	28.00	56.00	1	16	8	8.80	22.00	44.00	1	10	0	7.20	18.00	36.00	0	16	8	4.00	10.00	20.00
$\frac{19}{32}$	15	503·8	229	2	13	5	12.82	32.06	64.12	2	1	11	10.07	25.19	50.38	1	12	8	7.84	19.61	39.32	0	19	1	4.58	11.45	22.90
$\frac{5}{8}$	16	574·2	261	3	0	11	14.62	36.54	73.08	2	7	10	11.48	28.71	57.42	1	19	1	9.29	23.49	46.98	1	1	9	5.22	13.05	26.10
$\frac{25}{32}$	20	897·6	408	4	15	2	22.84	57.12	114.24	3	14	9	17.94	44.88	89.76	3	1	2	14.68	36.72	73.44	1	14	0	8.16	20.40	40.80

Table G.

(1)		(2)		(3)						(4)						(5)						(6)			
Diameter of Carbons in		Weight per 3,280 ft. = 1,000 metres.		Selling price per 3,280ft. = 1,000 metres.						Value of the raw material @ 2·8d. = 5.6cts. = 0.14fls. = 0.28frs. per 2·2lbs. = 1 kilo.						Amount left when raw material is deducted.						Amount left for profit and labour per 2·2lbs. = 1 kilo.			
Ins.	mm.	lbs.	kilos	£	s.	d.	$ ct.	fls.	frs.	£	s.	d.	$ ct.	fls.	frs.	£	s.	d.	$ ct.	fls.	frs.	Eng. pence.	U.S. cts.	fls.	frs.
Solid.																									
5/16	8	143·0	65	3	11	8	17.20	43.00	86.00	0	15	2	3.64	9.10	18.20	2	16	6	13.56	33.90	67.80	10·43	20.86	0.5215	1.0430
11/32	9	182·6	83	4	0	6	19.32	48.30	96.60	0	19	4	4.64	11.62	23.24	3	1	1½	14.67	36.68	73.36	8·838	17.676	0.4419	0.8838
13/32	10	226·6	103	4	9	8	21.52	53.80	107.60	1	4	0	5.76	14.42	28.84	3	5	7	15.75	39.38	79.76	7·626	15.252	0.3813	0.7626
7/16	11	272·8	124	4	18	6	23.64	59.10	109.20	1	8	11	6.94	17.36	34.72	3	9	6	16.69	41.74	83.48	6·732	13.464	0.3366	0.6732
15/32	12	323·4	147	5	7	6	25.80	64.50	139.00	1	13	5	8.02	20.06	40.12	3	14	0	17.77	44.44	88.88	6·046	12.092	0.3023	0.6046
1/2	13	380·6	173	6	0	10	29.00	72.50	145.00	2	0	4	9.68	24.22	48.44	4	0	5	19.31	48.28	96.56	5·58	11·16	0.2790	0.5580
9/16	14	440·0	200	7	3	4	34.40	86.00	172.00	2	6	8	11.20	28.00	56.00	4	16	8	23.20	58.00	116.00	5·8	11.6	0.2900	0.5800
23/32	18	728·2	331	12	0	8	58.00	145.00	290.00	3	17	3	18.54	46.34	92.68	8	4	5	39.46	98.66	197.32	5·96	11.92	0.2980	0.5960
Cored.																									
13/32	10	226·6	103	5	2	10	24.68	61.70	123.40	1	4	0	5.76	14.42	28.84	3	18	9	18.91	47.28	94.56	9·18	18.36	0.4590	0.9180
7/16	11	272·8	124	5	11	10	26.84	67.10	134.20	1	8	11	6.94	17.36	34.72	4	2	11	19.89	49.74	99.48	8·022	16.044	0.4011	0.8022
15/32	12	223·4	147	6	0	10	29.00	72.50	145.00	1	13	5	8.02	20.06	40.12	4	7	5	20.97	52.44	104.88	7·134	14.268	0.3567	0.7134
1/2	13	380·6	173	6	18	10	33.32	83.30	166.60	2	0	4	9.68	24.22	48.44	4	18	5	23.63	59.08	118.16	6·83	13.76	0·3415	0.6830
9/16	14	440·0	200	7	16	8	37.60	94.00	188.00	2	6	8	11.20	28.00	56.00	5	10	0	26.40	66.00	132.00	6·6	13.2	0.3300	0.6600
19/32	15	503·8	229	9	3	6	44.04	110.10	220.20	2	13	5	12.82	32.06	64.12	6	10	0	31.22	78.04	156.08	6·816	13.632	0.3408	0.6816
5/8	16	574·2	261	10	10	6	50.50	126.30	252.60	3	0	11	14.62	36.54	73.08	7	9	7	35.90	89.76	179.52	6·878	13.756	0.3439	0.6878
23/32	18	728·2	331	13	4	0	63.36	158.40	316.80	3	17	3	18.54	46.34	92.68	9	6	9	44.82	112.06	224.12	6·764	13.528	0.3382	0.6764
25/32	20	897·6	408	16	11	6	79.56	198.90	397.80	4	15	2	22.84	57.12	114.34	11	16	4	56.71	141.78	283.56	6·95	13.90	0.3475	0.7950

Table H.

(1A)		(2A)		(3A)						(4A)						(5A)						(6A)			
Diameter of Carbons in		Weight per 3,280 ft. = 1,000 meters.		Selling price per 3,280ft. = 1,000 metres.						Value of the raw material @ 2·2d. = 4.4cts. = 0.11fls. = 0.22frs. per 2·21bs. = 1 kilo.						Amount left when raw material is deducted.						Amount left for profit and labour per 2·21bs. = 1 kilo.			
Ins.	mm.	lbs.	kilos	£	s.	d.	$ ct.	fls.	frs.	£	s.	d.	$ ct.	fls.	frs.	£	s.	d.	$ ct.	fls.	frs.	Eng. d.	U.S. cents.	fls.	frs.
Solid.																									
5/16	8	143·0	65	3	3	6	15.24	38.10	76.20	0	11	11	2.86	7.15	14.30	2	11	7	12.38	30.95	61.90	9·522	19.044	0.4761	0.9522
11/32	9	182·6	83	3	12	0	17.28	43.20	86.40	0	15	2	3.65	9.13	18.26	2	16	9	13.62	34.07	68.14	8·208	16.416	0.4104	0.8208
13/32	10	226·6	103	3	19	10	19.16	47.90	95.80	0	18	6	4.45	11.33	22.66	3	0	11	14.62	36.57	73.14	7·10	14.20	0.3550	0.7100
7/16	11	272·8	124	4	7	6	20.10	52.50	105.00	1	2	8	5.45	13.64	27.28	3	4	9	15.54	38.86	77.72	6·266	12.532	0.3133	0.6266
15/32	12	323·4	147	4	16	0	23.04	57.60	115.20	1	6	11	6.47	16.17	32.34	3	9	0	16.56	41.43	82.86	5·636	11.272	0.2818	0.5636
1/2	13	380·6	173	5	8	0	25.92	64.80	129.60	1	11	8	7.61	19.03	38.06	3	16	3	18.30	45.77	91.54	5·29	10.58	0.2645	0.5290
9/16	14	440·0	200	6	7	10	30.68	76.70	153.40	1	16	8	8.80	22.00	44.00	4	11	2	21.88	54.70	109.40	5·47	10.94	0.2735	0.5470
23/32	18	728·2	331	10	16	0	51.84	129.60	259.20	3	0	8	14.56	36.41	72.82	7	15	4	37.28	93.19	186.38	5·63	11.26	0.2815	0.5630
Cored.																									
13/32	10	226·6	103	4	11	8	22.00	55.00	110.00	0	18	6	4.45	11.33	22.66	3	12	9	17.46	43.67	87.34	8·478	16.956	0.4239	0.8478
7/16	11	272·8	124	4	19	8	23.92	59.80	119.60	1	2	8	5.45	13.64	27.28	3	16	11	18.46	46.16	92.32	7·444	14.888	0.3722	0.7444
15/32	12	223·4	147	5	8	0	25.92	64.80	129.60	1	6	11	6.47	16.17	32.34	4	1	0	19.45	48.63	97.36	6·616	13.232	0.3308	0.6616
1/2	13	380·6	173	6	3	6	29.64	74.10	148.20	1	11	8	7.61	19.03	38.06	4	11	9	22.02	55.07	110.14	6·366	12.732	0.3183	0.6366
9/16	14	440·0	200	6	19	10	33.56	83.90	167.80	1	16	8	8.80	22.00	44.00	5	3	2	24.76	61.90	123.80	6·18	12.36	0.3090	0.6180
19/32	15	503·8	229	8	3	8	39.28	98.20	196.40	2	1	11	10.08	25.19	50.38	6	1	8	29.20	73.01	146.02	6·374	12.748	0.3187	0.6374
5/8	16	574·2	261	9	7	8	45.04	112.60	225.20	2	7	10	11.48	28.71	57.42	6	19	9	33.55	83.89	167.78	6·428	12.856	0.3214	0.6428
23/32	18	728·2	331	11	15	8	56.56	141.40	282.80	3	0	8	14.56	36.41	72.82	8	14	11	42.00	104.99	209.98	6·342	12.684	0.3171	0.6342
25/32	20	897·6	408	14	15	8	70.96	177.40	354.80	3	14	9	17.95	44.88	89.76	11	0	10	53.00	132.52	265.04	6·496	12.992	0.3248	0.6496

while they should represent the price of high grade goods per 3,280ft. = 1,000 metres. Column (4) represents the value of the raw material contained in carbons of different diameters per 3,280ft. = 1,000 metres, and is obtained by multiplying column (2) with 2·8d. = 5·6cts. = 0.14fls. = 0.28frs., the price of the high grade mixture per 2·2lbs. = 1 kilogramme. Column (5) represents the sum that is left when the cost of the raw material is deducted from the selling price, and is obtained by deducting column (4) from column (3). Column (6) represents the amount remaining from the selling price after the raw material has been deducted per 2·2lb. = 1 kilogramme: in other words, shows the sum per 2·2lb. = 1 kilogramme of carbon from which cost of labour, &c., has yet to be deducted in order to get at the net profits. This is obtained by dividing column (5) by column (2). For the purpose of calculation we will take the mean of the figures given in column (6), which is 7·186d. = 14·372cts. = 0.3593fls. = 0.7186frs. These figures represent the smallest nett sum a carbon manufacturer obtains for 2·2lb. = 1 kilogramme of electric light carbons, from which the costs of the raw material has already been deducted, and from which we must now deduct cost of labour, &c., to arrive at the nett actual profits.

It will be seen that the author has only taken into consideration such diameters of carbons as are chiefly used in practice, while he has also taken the weight of the cored carbons as the same as the solids, which leaves again a small margin, as, in reality, cored carbons are lighter in weight.

Table H is similar to the one just explained, and represents the same figures in regard to second-grade goods. In this Table the prices in column (3A) are taken from the same manufacturer's price list for second grade goods and from these prices also 40 per cent. discount is taken. The figures given in column (4A) are the values of the raw material for second grade mixture which, as we have seen in Table D, was taken at 2·2d. = 4·4cts. = 0·11fls. = 0.22fr. per 2·2lb. = 1 kilogramme. From column (6A) we find the mean to be about 6·696d. = 13·392cts. = 0·3348fls. = 0.6696fr.

We thus obtain from Tables G and H two constants, namely, 7·186d. = 14·372cts. = 0·3593fls. = 0.7186fr. and 6·695d. = 13·392cts. = 0·3348fls. = 0.6696fr., which give us, as has already been explained, the amount remaining to the carbon manufacturers per 2·2lb. = 1 kilo. of carbon; and it now only remains to get at the necessary allowances for labour, interest on capital and other expenses, which must be deducted from the above constants in order to get at the nett profits. The estimate which follows is for a factory that can turn out about 4,400lb. = 2,000 kilos. of carbon material per day of 10 hours (taking 300 working days per annum).

Table I.—*Estimate for Special Machinery used in Carbon Factories.*

——	£	s.	d.	$ cts.	Florins.	Francs.
1 Crushing machine	52	10	0	252.00	630.00	1,260.00
2 Crushings mills with runners	160	0	0	768.00	1,920.00	3,840.00
2 Roller mills (4)	148	0	0	710.40	1,776.00	3,552.00
2 Wet mixers	118	0	0	566.40	1,416.00	2,832.00
2 Roller mills for kneading (4)...	148	0	0	710.40	1,776.00	3,552.00
2 Cake pounders	58	6	8	280.00	700.00	1,400.00
1 Hydraulic press for cakes	377	10	0	1,812.00	4,530.00	9,060.00
1 Press pump with 5 cylinders	185	0	0	888.00	2,220.00	4,440.00
2 Forms for the cakes, &c.	100	0	0	480.00	1,200.00	2,400.00
1 Hydrl. presses for squirting (3)	335	0	0	1,608.00	4,020.00	8,040.00
1 Press pump with 5 cylinders	135	0	0	648.00	1,620.00	3,240.00
2 Hydraulic press for squirting (1)	350	0	0	1,680.00	4,200.00	8,400.00
2 Press pumps with 3 cylinders	140	0	0	672.00	1,680.00	3,360.00
2 Binding forms	10	0	0	48.00	120.00	240.00
1 Small crush'g mill with runners	27	10	0	132.00	330.00	660.00
1 Small crusher	17	10	0	84.00	210.00	420.00
1 Dry mixer	24	0	0	115.20	288.00	576.00
8 Coring presses.....................	56	0	0	268.80	672.00	1,354.00
6 Pointing machines	110	13	4	531.20	1,328.00	2,656.00
4 Cutting machines	61	6	8	294.40	736.00	1,472.00
1 Exhaustor	12	0	0	57.60	144.00	288.00
Mouthpieces and sundries......	123	13	4	593.60	1,484.00	2,968.00
Packing and Freight	108	6	8	520.00	1,300.00	2,600.00
Duty, &c............................	397	10	0	1,908.00	4,770.00	9,540.00
Placing machines, &c., in posit'n	77	10	0	372.00	930.00	1,860.00
Total amount	3,333	0	0	16,000.00	40,000.00	80,000.00

The entire estimate, it should be noted, is calculated to suit the conditions that exist in Austria-Hungary, while the special machinery is supposed to be purchased from a factory in Germany.

Estimate of capital outlay required in the establishment of a carbon factory for an output of about 2,000 kilogrammes per day for 300 working days per year (the carbonising furnaces working continuously) :—

Table K.

——	£	s.	d.	$ cts.	Florins.	Francs.
Special carbon machinery (as Table I.)	3,333	0	0	16,000.00	40,000.00	80,000.00
100 H.P. steam engine and boiler	1,916	13	4	9,200.00	23,000.00	46,000.00
Factory buildings, foundations, &c.	2,916	13	4	14,000 00	35,000.00	70,000.00
Mendheim's carbonising chamber system of furnace, &c.	2,000	0	0	9,600.00	24,000.00	48,000.00
Electric lighting plant	250	0	0	1,200.00	3,000.00	6,000.00
Water and heating pipes	208	6	8	1,000.00	2,500.00	5,000.00
Transmission plant, &c.	250	0	0	1,200.00	3,000.00	6,000.00
Belting, &c.	166	13	4	800.00	2,000.00	4,000.00
Factory utensils, &c.	166	13	4	800.00	2,000.00	4,000.00
Small chain hoist, &c.	41	11	4	200.00	500.00	1,000.00
Large scales for weighing, &c.	91	13	4	440.00	1,100.00	2,200.00
1,000 retorts for packing carbons, &c.	300	0	0	1,440.00	3,600.00	7,200.00
Oil filter	5	8	4	26.00	65.00	130.00
Tar tanks	41	11	4	200.00	500.00	1,000.00
Drying oven and stove for heating tar, &c.	133	6	8	640.00	1,600.00	3,200.00
Machinery and tools for repair shop, &c.	250	0	0	1,200.00	3,000.00	6,000.00
Office furniture	41	11	4	200.00	500.00	1,000.00
Testing room instruments, &c.	83	6	8	400.00	1,000.00	2,000.00
Chemical laboratory, instruments, &c.	83	6	8	400.00	1,000.00	2,000.00
For reserve sundries, &c.	178	8	4	854.00	2,135.00	4,270.00
Total amount of capital necessary (in round figures)	12,500	0	0	60,000.00	150,000.00	300,000.00

The above estimate is a very liberal one, and it may be safely asserted that the capital actually necessary is considerably less, but for the purpose in view it is well to make liberal allowances for contingencies. It may also be pointed out that nowadays electric power can be obtained in many places very cheaply, especially where water-power is available, so that a new carbon factory established where such power can be obtained would do away with the item relating to the steam engine, &c.

Anyone who is acquainted with the price of labour in Austria-Hungary or Germany will see that the author has taken fairly high figures for this item. The author has had experience in a carbon factory, and knows that the average

Table L.—*Labour required in a Carbon Works producing about 4,400lbs. = 2,000 kilos. of material per day of 10 hours, and taking 300 working days per year.*

—	£	s.	d.	$ cts.	Florins.	Francs.	Total per Annum. £	s.	d.	$ cts.	Florins.	Francs.
Two men for crushing machines per day.........	0	2	0	0.48	1.20	2.40	60	0	0	288.00	720.00	1,440.00
„ „ crushing mill „	0	2	0	0.48	1.20	2.40	60	0	0	288.00	720.00	1,440.00
„ „ roller mills „	0	2	0	0.48	1.20	2.40	60	0	0	288.00	720.00	1,440.00
„ „ wet mixers „	0	2	0	0.48	1.20	2.40	60	0	0	288.00	720.00	1,440.00
„ „ kneading mills „	0	2	0	0.48	1.20	2.40	60	0	0	288.00	720.00	1,440.00
„ „ cake pounders „	0	2	0	0.48	1.20	2.40	60	0	0	288.00	720.00	1,440.00
Six men for the presses „	0	2	4	0.56	1.40	2.80	210	0	0	1,008.00	2,520.00	5,040.00
„ „ binding and packing „	0	2	0	0.48	1.20	2.40	180	0	0	864.00	2,160.00	4,320.00
Two men for dry mixers „	0	2	0	0.48	1.20	2.40	60	0	0	288.00	720.00	1,440.00
Eight men for pointing „	0	2	0	0.48	1.20	2.40	240	0	0	1,152.00	2,880.00	5,760.00
„ „ cutting „	0	2	0	0.48	1.20	2.40	240	0	0	1,152.00	2,880.00	5,760.00
Two men for Mendheim furnace @ 365 days per year, one for day and one for night.	0	2	6	0.60	1.50	3.00	91	5	0	438.00	1,095.00	2,190.00
Twenty-five labourers for helping, per day	0	1	8	0.40	1.00	2.00	625	0	0	3,000 00	7,500.00	15,000.00
Seven men or girls for coring „	0	1	8	0.40	1.00	2.00	175	0	0	840.00	2,100.00	4,200.00
One box or case maker „	0	2	0	0.48	1.20	2.40	30	0	0	144.00	360.00	720.00
„ machinist „	0	5	0	1.20	3.00	6.00	75	0	0	360.00	900.00	1,800.00
Three helpers for machinist „	0	2	6	0.60	1.50	3.00	112	10	0	540 00	1,350.00	2,700.00
One store-room keeper „	0	2	6	0.60	1.50	3.00	37	10	0	180.00	450.00	900.00
„ engine driver „	0	4	2	1.00	2.50	5.00	62	10	0	300 00	750.00	1,500.00
„ man for boiler „	0	2	6	0.60	1.50	3.00	37	10	0	180.00	450,00	900.00
Two men, night and day watchman, per week	0	15	0	3.60	9.00	18.00	78	0	0	374.40	936.00	1,972.00
One foreman, per month	10	0	0	48.00	120.00	240.00	120	0	0	576.00	1,440.00	2,880.00
Three clerks „	8	6	8	40.00	100.00	200.00	300	0	0	1,440.00	3,600.00	7,200.00
Two travellers „	10	0	0	48.00	120.00	240.00	240	0	0	1,152.00	2,880.00	5,760.00
One director or chief		...		...	...	...	416	13	4	2,000.00	5,000.00	10,000.00
Total amount per annum for labour							3,691	0	0	17,716.00	44,291.00	88,582.00

rates are much lower. The figures of the estimate are therefore high, and at the same time the numbers of men given are more than sufficient for the work.

Table M.—*Estimate List of Yearly Expenses.*

—	£	s.	d.	$ cts.	Florins.	Francs.
1 Labour, &c.	3,691	0	0	17,716.00	44,291.00	88,582.00
2 Coal for Boilers and Mendheim Furnace................	1,250	0	0	6,000.00	15,000.00	30,000.00
3 Oil, Waste, &c.	125	0	0	600.00	1,500.00	3,000.00
4 Water	50	0	0	240.00	600.00	1,200.00
5 Repairs per annum	583	6	8	2,800.00	7,000.00	14,000.00
6 Retorts, Fire-bricks, &c. ...	500	0	0	2,400.00	6,000.00	12,000.00
7 Belting, &c.	66	13	4	320.00	800.00	1,600.00
8 Wood for Cases, Nails, Iron Straps, &c.	291	13	4	1,400.00	3,500.00	7,000.00
9 Office Expenses, Postage, Printing, &c.	433	6	8	2,080.00	5,200.00	10,400.00
10 Travellers' Expenses, &c....	583	6	8	2,800.00	7,000.00	14,000.00
11 Advertising, &c.	342	8	4	1,403.60	3,509.00	7,018,00
12 Insurance, &c.	50	0	0	240.00	600.00	1,200.00
13 10 per Cent. Redemption on Capital Outlay.........	1,250	0	0	6,000.00	15,000.00	30,000.00
14 Foreign Expenses, &c.	1,666	13	4	8,000.00	20,000.00	40,000.00
Total Annual Expenses...	10,833	0	0	52,000.00	130,000.00	260,000.00

Item (1) in the Table M is taken from Table L, which has been shown to be very liberally calculated.

Item (2), which represents the coal bill, is possibly larger than is necessary, for if we reckon 5·5lb. = 2·5 kilo. of coal per H.P. for 100 H.P. engine that, however, really works on an average with 80 H.P. for ten hours a day, while we can take the average consumption of coal used by the Mendheim chamber furnace at about 165lb. = 75 kilo. per hour (for 4,400lb. = 2,000 kilo. of carbons carbonised per 24 hours), we find that £1,250 = $6,000 = 15,000·00fls. = 30,000frs. per year, will, under all considerations, be sufficient, coal costing from 1s. 4d. to 1s. 7d. = 32 to 38cts. = 0·80 to 0·95fls. = 1·60 to 1·90frs. per 220lb. = 100 kilo.

Items (3) and (4) need no explanation, as facts show the amount given to be sufficient.

Item (5) is for repairs to machinery, &c., which generally amounts to about £333 to £416 = $1,600 to $2,000 = 4,000fls. to 5,000fls. = 8,000frs. to 10,000frs. per year, while the author has taken £583 = $2,400 = 7,000fls. = 14,000frs. in order to have a good margin.

Item (6).—The retorts cost about 3s. 3d. = 80cts. = 2·00fls. = 4·00frs. each, and the average number of times they can be used may be taken as from 15 to 20, but when using a Mendheim furnace, where the flames do not strike the retorts horizontally, they can usually be employed more than 20 times, so that the amount given in this item is again ample.

Item (7) shows the belting, being mostly of a small width, the sum given will be found enough.

Item (8) shows the author has given a sum of £291. 13s. 4d. = $1,400.00 = 3,500.00fls. = 7,000frs. for cases and packing, although purchasers of carbons usually have to pay the cost of packing, &c. Estimate L, however, provides a case maker, and, therefore, the sum for boards, cases, &c., which can be made very cheaply, is a liberal one.

Item (9) needs no explanation.

Item (10) includes such expenses as are usually allowed to travellers. It may be taken that on an average the traveller in carbons is out on the road about 200 days in the year, and he is allowed about 12.00fls. (£1 or $4.80 or 25frs.) per day for all expenses. This would make about £400 = $1,920.00 = 4,800.00fls. = 9,600frs. for such expenses for two travellers, The amount taken in the estimate is, therefore, sufficient, and any surplus may represent the sum required for tips, &c. In the carbon trade these tips are given to trimmers, &c., and are a recognised custom. The only way to get rid of so unsatisfactory a practice is for the engineer of the carbon-using firm to test the carbons himself and report as to the results of such tests.

Items (11) and (12) need no explanation.

Item (13) allows 10 per cent. of the capital expended for redemption, and this is, in the author's opinion, very liberal, as 5 per cent. would more nearly represent the actual figure. This is from the author's experience in a factory which has been established more than 15 years.

Item (14) represents expenses which may occur when a manufacturer has foreign agencies, pays rent for storage, duty and other charges. It is a large sum and is, in fact, scarcely a legitimate item to be included in the yearly expenses, as it should come out of the higher prices made for carbons in foreign countries. For example, ½in. (= 13mm.) cored carbons are sold to customers giving very large orders at about $40.00 (£8. 6s. 8d. = 104fls. = 208frs.) per 3,280ft. = 1,000 metres in the United States. The author, however, bases his calculations in this estimate on the price of £6. 18s. 10d. (= $33.32 = 83.30fl. = 166.60frs. per 3,280ft. = 1,000 metres of 13mm. = ½in. carbons. This makes a difference of £1. 7s. 10d. (= $6.68 = 16.70fls. = 33.40frs.), and this would cover freight, storage and a portion of the duty, although not all. The remainder of the money required for duty can thus be taken out of the £1,666. 13s. 4d. (= $8,000.00 = 20,000fls. = 40,000frs.) given in item (14). It is, however, probable that very little business can be done with the United States now, on account of the heavy duties imposed on imported carbons, or that only the highest grade of goods will now be purchased from European makers. Formerly large quantities of second and third grade carbons were sent from Europe to the United States, which passed there as high-grade carbons.

The cost of raw material for making carbons does not appear in the estimate of the yearly expenses, as that has already been deducted in Tables G and H, so that it does not enter into our accounts now, as we have obtained constants, namely, 7·186d. (= 14.372cts. = 0.3593fls. = 0.7186frs.) for the first grade, and 6·696d. = 13·392cts. (= 0.3348fls. = 0.6696frs.) for the second-grade carbons, which represent the price a carbon manufacturer receives for 2·2lb. = 1 kilogramme of carbon where cost of raw material has been deducted, and labour and other expenses must be deducted to get at the profits.

We have seen from Table K that the capital necessary for building a first-class carbon factory is about £12,500 (= $60,000 = 150,000.00fls. = 300,000frs,), and if we add to this still another £10,417 (= $50,000 = 125,000.00fls. = 250,000frs.) as working capital, this is a very liberal allowance. We have thus :—

—	£	Dollars.	Florins.	Francs.
Capital necessary for building and equipping a complete works for manufacturing electric light carbons, &c.	12,500	60,000	150,000.00	300,000.00
Working capital necessary for same	10,417	50,000	125,000.00	250,000.00
Total capital	22,916	110,000	275,000.00	550,000.00

This data will enable us to calculate what profits there are to be made from the carbon manufacturing industry.

For high-grade goods we find that by manufacturing about 4,400lb. = 2,000 kilogrammes per day we produce per year 2,000 × 300 = 600,000 kilogrammes = 1,560,000lb., which, when sold at the low price of 7·186d. (= 14·372cts. = 0.3593fls. = 0.7186fr.) our constant for high-grade carbons per 2·2lb. = 1 kilogramme, brings us per year the gross sum of £17,965 (= $86,232 = 215,580fls. = 431,160frs.) Deducting the yearly expenses from this sum we have—

—	£	Dollars.	Florins.	Francs.
	17,965	86,232	215,580	431,160
Yearly expenses, Table (M)........	10,833	52,000	130,000	260,000
	7,132	34,232	85,580	171,160

This represents about 31 per cent. interest on a capital of £22,916 = $110,000 = 550,000frs. = 275,000.00fls. invested in building and equipping a carbon factory, &c. Rates and taxes have not been deducted from the above profits, but these will not reduce the profits materially.

If we make a similar calculation with regard to the second grade of goods, using the second-grade constant, 6·696d. (= 13·392cts. = 0.3348fls. = 0.6696frs.) we find we obtain £16,740 (= $80,352 = 200,880fls. = 401,760frs.) Deducting yearly expenses from this sum we have—

—	£	Dollars.	Florins.	Francs.
	16,740	80,352	200,880	401,760
Yearly expenses, estimate (D)......	10,833	52,000	130,000	260,000
	5,907	28,352	70,880	141,760

This is more than 25 per cent. on the capital invested.

Considerable quantities of carbons were formerly exported from Europe whose quality was about the same as those given in Table K, and were designated as third grade. These carbons passed as high-grade goods in many foreign countries. Any connoisseur of carbon brands, however, would have pronounced them as third rate, and when burning they threw off quantities of dust, while the light emitted was yellow compared with that from high-grade carbons. They had also a higher resistance than others made of pure soot. When broken in two, and on examining the surface, small white specks and flaws, having a different colour from the main body of the carbon, could be detected, indicating the presence of gas retort carbon or petroleum coke. High-grade carbons, made of pure soot, present when broken no such specks, but have a perfectly homogeneous surface, and when held in the sunlight the rainbow-tinted rings can be observed.

From Table F we see that a factory producing about 4,400lbs. = 2,000 kilogrammes of carbons per day equals approximately the following quantities of the various sizes :—

$\frac{5}{16}$in.=	8mm.	carbons=	about	30,000	metres, or	98,427ft.
$\frac{11}{32}$ „	9	„	„	24,000	„	78,741ft.
$\frac{13}{32}$ „	10	„	„	19,000	„	62,339ft.
$\frac{7}{16}$ „	11	„	„	16,000	„	52,496ft.
$\frac{15}{32}$ „	12	„	„	14,000	„	45,934ft.
$\frac{1}{2}$ „	13	„	„	12,000	„	39,372ft.
$\frac{9}{16}$ „	14	„	„	10,000	„	32,810ft.
$\frac{19}{32}$ „	15	„	„	9,000	„	29,529ft.
$\frac{5}{8}$ „	16	„	„	8,000	„	26,248ft.
$\frac{23}{32}$ „	18	„	„	6,000	„	19,686ft.
$\frac{25}{32}$ „	20	„	„	5,000	„	16,405ft.

The $\frac{15}{32}$in. = 12mm. carbon can be taken as the average size, so that a carbon factory producing about 4,400lbs. = 2,000 kilogrammes of carbon per day makes about 14,000 metres or 46,000ft. of this size per day.

From these calculations we obtain a practical approximate idea of the profits made in the manufacture of carbons, and at the same time an idea how large these profits must have been a few years ago when the price of carbons was more than double the figure of to-day. It has been seen throughout these calculations that liberal margins have been given at every step, so that, on the whole, the author feels he can with certainty affirm that in carbon manufacture there is a gain of from at least 25 per cent. to 30 per cent. on capital invested, while it may be even higher for new factories starting in countries where the industry heretofore has not existed, as such a factory can to day profit from the long series of costly experiments that the owners of the older works have had to carry out before they reached the perfection that now exists in machinery, furnaces and apparatus in use.

The author finally recommends any one thinking of starting such a factory to consider that they will find it to their best interest to order the machinery and furnaces only from those manufacturers who have had many years' experience in building them.

CHAPTER XII.

THE MANUFACTURE OF ELECTRODES ON A SMALL SCALE.

The financial success of many electro-chemical or smelting works is often dependent upon the cost of the electrodes they employ, which in most cases are made from carbon. It would, no doubt, be to the interest of such concerns to manufacture their own electrodes, and the following estimate will give the approximate cost of a small plant that can produce about 500 kilos. (1,100lbs.) of electrodes per day, or 3,000 kilos. (6,600lbs.) per week.

In the following estimate a Braun hydraulic press, No. 3, is taken, which can squirt electrodes having a width up to 180mm. (7″). If larger sizes are required than the above, a Braun hydraulic press No. 5 must be employed, which can produce electrodes having a width up to 500mm. (19·5″). Such a press would increase the cost of the plant about £541. 6s.(= $2,600 = 6,500.00fl. = 13,000fr.). Press No. 3 can work off about 1,300 kilos. (2,860lbs.) per day, and press No. 5 about 13,000 kilos. (28,600lbs.) We see thus a press in a plant that only makes about 500 kilos. (1,100lbs.) works only a few hours every day.

It may also be mentioned that in the following calculations the price of the raw material (common mixture, Tables B and D) is taken at 0.05fl. (1d. or 2.5cts.) per kilo., and the material consists of either petroleum coke, or gas retort carbon mixed with tar. However, in many cases common coke, as obtained at any gas works, is just as suitable for making electrodes, while its cost is less than half. Works that produce carborundum, calcium carbide, or aluminium, &c., will find that electrodes made of common coke will answer their requirements. It is well when buying the coke to pay a little more per ton, and have only dense pieces picked out, which are better suited for making electrodes. In the estimate the writer has taken the low figure of 0.20fl. (4d. or 8cts.) per kilo. as the cost of the finished electrodes, although it is not probable that any concern can buy their electrodes at such a low price.

It is supposed that power is at hand (about 10-12 H.P.), also a small space where the machinery can be set up, and for both an item of rent will be inserted in the yearly expenses.

Cost of Machinery for Making Electrodes, &c.

1 Crushing machine	£52	10	0	$252.00	fl.630.00
1 Crushing mill with runners	80	0	0	384.00	960.00
1 Roller mill, No. 2	50	0	0	240.00	600.00
1 Wet mixer	54	3	4	260.00	650.00
1 Roller mill for kneading	50	0	0	240.00	600.00
1 Cake pounder	30	0	0	144.00	360.00
1 Hydraulic press, No. 3	335	0	0	1,608.00	4,020.00
1 Five-cylinder press pump	135	0	0	648.00	1,620.00
Sundries	46	13	4	224.00	560.00
Packing, freight, duty & erecting	166	13	4	800.00	2,000.00
Total	£1,000	0	0	$4,800.00	fl.12,000.00

Complete Plant.

Special machinery	£1,000	0	0	$4,800.00	fl.12,000.00
Foundations, &c.	25	0	0	120.00	300.00
Mendheim furnace for electrodes	1,000	0	0	4,800.00	12,000.00
Countershafts, belting, &c.	58	6	8	280.00	700.00
Utensils and small tar tank	25	0	0	120.00	300.00
Sundries	58	6	8	280.00	700.00
Total sum	£2,166	13	4	$10,400·00	fl.26,000·00

Labour Necessary.

6 men at fl.1.20 (2s. or 48cts.) per day, or per year of 300 days	£180	0	0	$864.00	fl.2,160.00
1 man at fl.3.00 (5s. or $1.20) per day, or per year of 300 days	75	0	0	360.00	900.00
2 men for the furnace, or per year of 365 days	91	5	0	438.00	1,095.00
	£346	5	0	$1,662.00	fl.4,155.00

Yearly Expenses.

	£	s.	d.	$	fl.
Labour	£346	5	0	$1,662.00	fl.4,155.00
Coal for furnace	166	13	4	800.00	2,000.00
Oil and waste	25	0	0	120.00	300.00
Fire bricks, &c.	66	13	4	320.00	800.00
Belting, &c.	8	6	8	40.00	100.00
Repairs, &c.	208	6	8	1,000.00	2,500.00
Rent for power (average, 10 H.P)	166	13	4	800.00	2,000.00
Rent for space in the works	41	13	4	200.00	500.00
Insurance	6	5	0	30.00	75.00
10 per cent. redemption on fl.26,000.00	216	13	4	1,040.00	2,600.00
Sundries	22	10	0	108.00	270.00
	£1,275	0	0	$6,120·00	fl.15,300.00
Capital invested in electrode plant	£2,166	13	4	$10,400.00	fl.26,000.00
Working capital put in	833	6	8	4,000.00	10,000.00
Total capital considered as invested	£3,000	0	0	$14,400.00	fl.36,000.00

1,100lbs. = 500 kilos. electrodes per day is about 330,000lbs. = 150,000 kilos. per year. At the low price of 4d. (8cts. or fl.0.20) per kilo. (2.2lbs.) we have:—

$$\frac{330,000}{2.2} \times 4 = £2,500, \text{ or } \frac{330,000}{2.2} \times 8 = \$12,000, \text{ or } 150,000 \times .2 = \text{fl. } 30,000.$$

Raw mixture at 1d. = 2cts. = fl.0.05 per kilo:—

$$\frac{330,000}{2.2} \times 1 = £625, \text{ or } \frac{330,000}{2.2} \times 2 = \$3,000, \text{ or } 150,000 \times .05 = \text{fl.}7,500.$$

	£	$	fl.
Expenses per year	£1,275	$6,120.00	fl.15,300.00
Raw material	625	3,000.00	7,500.00
Total	£1,900	$9,120.00	fl.22,800.00
Price of electrodes	£2,500	$12,000.00	fl.30,000.00
Expenses	1,900	9,120.00	22,800.00
Profits	£600	$2,880.00	fl.7,200.00

This shows that when electro-chemical works or smelting concerns make their own electrodes, they can produce them at about £1. 13s. 4d. = $8.00 = fl.20.00 per 100 kilos. (220lbs), and yet have a profit on the money they invest, or, in other words, they can produce their electrodes at less than £1. 13s. 4d. = $8.00 = fl.20.00 per 100 kilos., when they desire only an interest of 5 per cent. on the capital invested.

In carborundum works there is a by-product of good carbon which will make excellent electrodes, so that such concerns have at hand a very cheap raw material which can be considered as costing them hardly anything. It is obvious that when a factory needs more than about 500 kilos. (1,100lbs.) of electrodes per day, the cost of manufacturing will not increase proportionally, as the more they make the cheaper will be the price of production per kilo. up to a certain limit. The author has calculated, for instance, that when a carbon firm invests about £600 ($2,880 or fl.7,200) for an electrode plant that can produce about 4,000 kilos. (8,800lbs.) per day, electrodes can be produced at about £1. 5s. ($6 or fl.15.00) per 100 kilos., at which price there will still be a profit of about 25 to 30 per cent. on the capital invested.

The main success in all enterprises is, of course, largely dependent upon the amount of goods that will be sold, which amount cannot with certainty be fixed beforehand, yet the author is of opinion that the carbon industry would thrive well in England, while in the United States high grade carbon factories must, under all circumstances, prosper, as there is a growing demand for such brands. The fact that Europe has been sending large quantities of carbons, &c., to both these countries is enough to warrant the establishment of such works. A carbon factory, as has already been mentioned, should have its own soot works, and thus obtain a greater margin profit, as soot can no doubt be produced at about 20 to 30 per cent. less than the price the author has taken in his calculations.

Having a soot factory, printers' inks can also be made, as is done by a carbon factory in Austria. Blacking, crucibles, water filters, and other articles, the manufacture of which are all sister branches to the carbon industry, afford an extension in business that will help to swell the profits by the investment of a little extra capital. As carbon factories have good furnaces, there is no reason whatever why they should not make their own retorts in which the carbons are baked or carbonised, which will thus also cut down some of the yearly expenses. Only one or two extra machines are necessary for the purpose, by which the broken retorts are ground up, and, with the addition of fireclay (chamotte flour), new retorts can be moulded or pressed and baked in the same furnace as that in which the carbons are placed if there is room, or when the demand for carbons slackness down. The broken retorts furnish a very serviceable material, as they have been subjected to great heat.

CHAPTER XIII.

SOME POINTS IN BUILDING A CARBON FACTORY.

Many of the old carbon factories still in existence are simply a conglomeration of ill-adapted buildings and sheds, the situations of which do not allow of any systematic routine in working, as the material, when finished in one part, is often taken to opposite ends to another department, and thus the constant carriage to various parts of the works necessitates more labour and increases the working expenses of the plant. Fig. 65 represents the ground plan of a model factory designed by the author, estimated to produce about 2,000 kilos. of carbons per day of 10 hours. The style of roofing is shown in Fig. 66, and it will be seen that this form gives good lighting and ventilation, as the windows on the roof are made to slide, or extra ventilation shafts can easily be fixed. From the ground plan we see that there is ample room for increasing the output of the factory, while if it is desired to extend any special department this is easily effected, as the roof rests at the ends on iron pillars shown at *r*, which permits the side wall to be taken down and an extension built. The heavy arrows show the direction in which the factory can be enlarged. It is, of course, understood that when a plot of ground is bought for such a factory it should be taken large enough to permit of any extensions that business may later on demand.

It will be seen from the ground plan that the proposed factory takes up about 1,770 square metres, or 1,935 square yards. It must be pointed out particularly again, that when a modern factory is built, it should always be so designed that it can be easily enlarged, while at the same time such enlargement should cause no disturbance in the regular routine of the work. In the author's design these conditions are

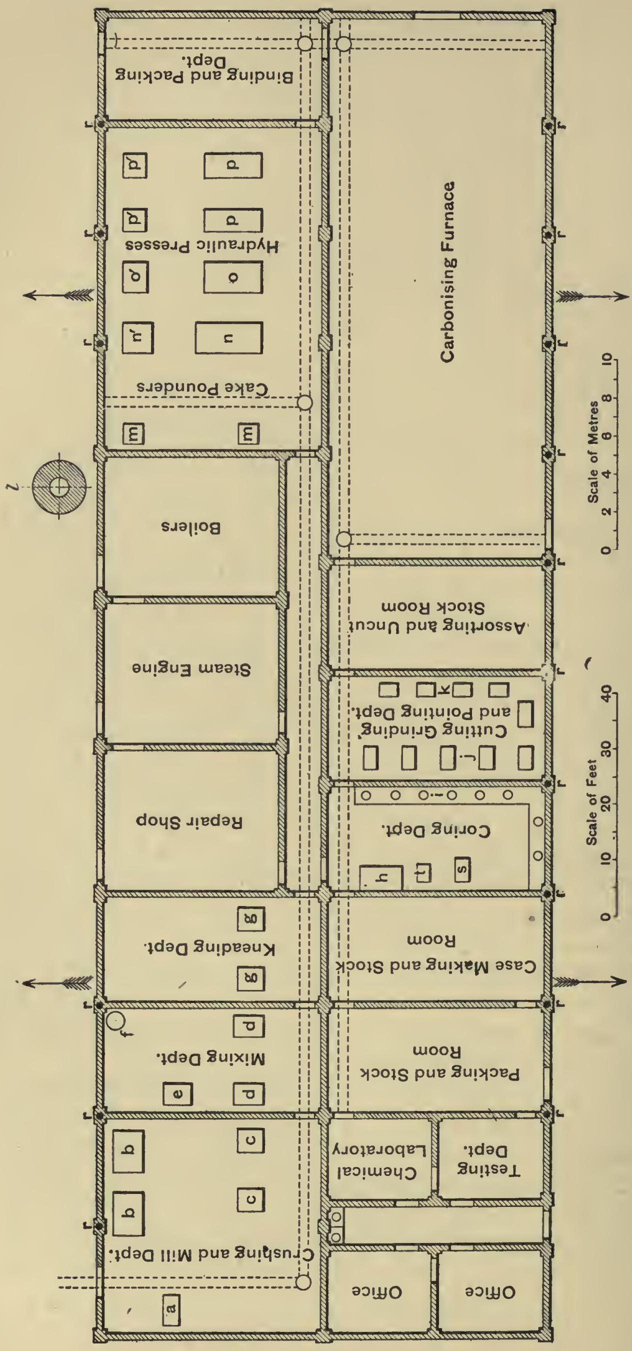


FIG. 65.—Model Factory for Manufacturing Electric Light Carbons. Designed by Francis Jehl.

fulfilled, as single or complete extensions can be made on both sides of the factory without interfering with the regular work. In addition to the factory there must be a watertight shed, in which the raw material is stored, a lavatory and bathing house for the workmen (this is compulsory in Europe), and the necessary sanitary arrangements.

The office corner of the factory can have an extra storey if more room is desired, while an extra room is built over it, between the mixing department and stock room, in which the bins are situated that contain the carbon flour and lampblack. This room can extend about 3 metres over the rooms just mentioned. The raw material is brought as it is wanted into the crushing and milling department from the outside shed on little iron waggons that run on rails, as shown. In the ground plan *a* represents the crusher, *b b* the crushing mills with vertical runners, and *c c* are the roller mills. After the raw material has been ground into flour it is elevated into the bins, from which it is taken as wanted by means of spouts that lead into the mixing department. Here *d d* are the wet mixers and *e* the dry mixer, while *f* is the tar tank that is heated by waste steam. The larger reservoir containing tar, and not shown in the drawing, can be built in the ground in front of the engine room. This reservoir should also be heated by waste steam, and provided with a suitable cock, by which the water that the tar may contain can be blown off, as this settles when the tar is warm. This reservoir and the one shown at *f* is connected by a pipe and pump, so that *f* can always be filled. After the material is well mixed it is taken into the kneading department, where it is kneaded by the roller mills *g g*. When this operation is completed it is

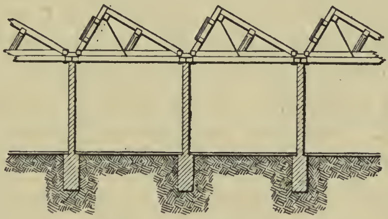


FIG. 66.—Longitudinal Section.

transferred to the cake pounders *m m*, and from there to the cake hydraulic press *n*, where *n′* is the press pump, *o p p* are the hydraulic presses that squirt the carbons, and *o′ p′ p′* are their respective press pumps. The carbon rods are then taken to the binding department, where they are tied up in bundles and packed in retorts, which are taken to the furnace house. The author has designed this part of the factory large enough for any kind or system of furnace that has been explained, while at the same time it can be extended on two sides, if necessary.

After the goods have been carbonised they are taken to the sorting room, where also the carbon rods can be stored when the factory is working for stock. From this stock, as orders come in, the desired sizes are taken and brought into the cutting, &c., department, where the rods are cut down to their proper length by the machines shown at *k*, and ground and pointed by the machines *j*. The ventilator that sucks the carbon dust from the pointing and grinding machines is not shown in the drawing, but it can easily be placed on a bracket near the roof. After the carbons are finished in this department they are taken to the coring room, where *i* indicates the coring presses that are placed on a table along the wall. The carbons are dried in the oven *h*, while *t* and *s* represent the small crusher and mixing machine used in the preparation of the coring mixture.

When the carbons are finished in this department they are taken into the packing room, where they are tied up in bundles, wrapped in paper and labelled. They are then either packed in cases and shipped or stored away on the shelves of the stock room. The remainder of the departments shown in the drawing explain themselves, and it will be seen that the whole group is so designed that from the time when the raw material enters the factory, it travels, as it is worked up, directly from one department to another, and makes one direct continuous circuit until the finished goods are delivered into the packing room. Each department is connected by a railway, thereby facilitating carriage and saving time and labour.

It will be seen that the engine room is situated in the middle of the factory, and that the power is thus distributed on both sides pretty nearly evenly, while the furnace flue can be connected with the chimney by a small length of passage. If, instead of steam power, electric power can be obtained from an adjacent watercourse, the length of the factory can be decreased or the extra space used for the extension of the hydraulic press department.

A well-situated carbon factory should be near to, or have a side track connecting it with, a railway, so that fuel can be simply unloaded direct from the trucks, while the carbons can be directly packed into freight cars at the works, as such facilities save the expense of cartage.

CHAPTER XIV.

SOOT OR LAMPBLACK.

The rational working of a carbon factory demands, also, the establishment of works where the soot or lampblack used in the making of high-grade carbons can be manufactured. Lampblack, soot or amorphous carbon is largely manufactured by heating on a hearth vegetable or mineral matters composed of hydrocarbons. When the vapours are disengaged they are ignited and allowed to burn by supplying just air enough to keep up the combustion—that is, air enough to keep the flames alive, but insufficient to produce complete combustion of the carbon contained in or liberated by the gases. The hydrogen which these substances contain, being its most inflammable part, burns off, leaving the carbon in a powdered or soot-like form. The smoke resulting from this incomplete combustion is allowed to pass through large chambers, where it settles down or condenses. The above are the principles on which large quantities of soot are manufactured, but when a very fine quality of lampblack is desired, oils are generally burned in special lamps, so that they smoke, and the smoke is allowed to condense in a manner similar to that explained above.

Many varieties of apparatus have been designed for producing soot or lampblack by allowing smoky flames to strike some cold surface, on which condensation is effected immediately; this is, however, not necessary, as the quality and efficiency of production can be effected better by allowing the smoke to condense in chambers. On the whole, however, the author thinks there is plenty of room for further improvement in soot manufacture, and that the long path taken by the sooty smoke in passing from chamber to chamber may yet be avoided. Perhaps favourable results could be obtained by forcing the smoke through water by means of an exhauster, in which water the soot would settle or float on the surface. It would then, of course, have to be dried or calcinated. Another way would be to let the smoke pass through a small chamber in which water was discharged in a spray. The lampblack slush could be collected from time to time, dried and calcinated. Such methods have the advantage of using a small building instead of the long ones now in use, while at the same time there would be a certainty of collecting all the lampblack produced. However, using water in order to catch lampblack has the disadvantage that it is necessary to calcinate the soot afterwards, or at least thoroughly dry it, which means extra labour. As a general rule, lampblack manufacturers in Germany are constrained to locate themselves in the open country or woods, because there is an escape of soot which settles on everything in the vicinity and blackens it.

Concerning the theory of the formation of lampblack or soot we must first take a glance at the nature of a flame. We know that it is necessary, in order to produce a flame, that the combustible used should be of such a nature as to be capable of being converted into a gas before it undergoes combustion, and that when this condition does not exist, no flame can be produced. Bodies may glow like a loop in an incandescent lamp or a heated piece of iron, but then there is no flame.

Flame can only be produced by a continuous supply of combustible vapours or gas, which combine with the oxygen of the air, and the particles of matter contained in the vapour are so heated that they emit light. Generally speaking, illuminating agents are compounds that are rich in carbon, on the presence of which depends the brightness of the flame.

If a flame contains no such solid particles of carbon, the light emitted will be feeble, as the brightness of a flame is due to the incandescent particles that act as so many radiant points. To get the best results as regards light with a given substance, the supply of air must be so proportioned that it is insufficient for instantaneous combustion; as then the hydrogen will take up the greater part of the oxygen, and a large portion of carbon will be precipitated and consumed in the solid form, giving a bright light. When we produce complete and immediate combustion, none, or very little, precipitation of carbon takes place, and the light will not be bright. Again, if the air supplied is insufficient to cause combustion of the newly-precipitated carbon, the flame will be smoky, and unburnt carbon will escape in the form of soot.

The flame of a candle may, for instance, be divided into three distinct parts. At *a*, in Fig. 67, we have the reservoir of unburnt gases that surround the wick, and which are produced by the decomposition of the melted wax that the heat of combustion converts into gaseous hydro-carbons. At the lower part of the flame *a′*, some of the gas gets mixed with air and burns with a pale blue light, while the greater part rises and surrounds the wick. If a small glass tube is inserted into this zone some of the gas will pass through the tube and may be lighted at the other end. This reservoir of gas is intensely heated by the combustion going on at its lower end, *a′*, as has already been explained, and this causes some of the more oxidisable hydrogen to undergo combustion as it reaches the second portion of the flame. The result is that carbon is precipitated and becomes intensely ignited, forming the luminous or second portion of the flame at *b*. Here we have an incomplete combustion going on, but as the remaining unburnt carbon gradually comes towards the surface, the last

Fig. 67.—Candle Flame.

portion of the flame, *c*, is produced, which is the non-luminous part or the area of complete combustion. If we place the flame in a strong draught of air, we shall notice that the portions of the flame described above will get distorted, while also a more immediate combustion results, which produces or emits very little light. If we place a glass chimney over the candle and allow very little air to enter from the bottom, we produce a smoky flame, giving off large quantities of soot. If we allow a little more air to enter by raising the chimney slightly we still have a smoky flame, but one that does not throw off such large quantities of soot as before, while if we should examine the quality of this soot, it will be found that it is superior to that obtained in the first experiment.

Thus, by regulating the admission of air, we can produce soot either in good quality or quantity. In other words, the higher the rate of combustion at which soot is produced, the better will be its quality, and *vice versâ*. The above are, therefore, the principals that govern the production of soot in a factory. If we raise the chimney still higher and admit more air we find that the intensity of the light increases until a certain limit is reached, after which it may in certain circumstances decrease again in brightness, if there is a strong draught, but it will now not smoke.

It was Sir H. Davy * who first set up the hypothesis that the light emitted in an ordinary flame was due to small particles of solid carbon that become heated to incandescence. This theory was at one time contested, as it was supposed that the luminosity was due to the incandescence of gaseous hydrocarbons of great density. However, the experiments of Stein and Heumann proved that Davy's supposition was correct. It was shown that chlorine, which decomposes hydrocarbons at a red heat with separation of carbon, when introduced into a feebly luminous hydrocarbon flame, increases its luminosity. Also that heated and cold surfaces become covered with soot when held in a flame, showing that this deposit of soot is not the result of the condensation of dense hydrocarbon vapours. If a rod is held in the flame of a gas

---

* Miller's "Chemistry."

jet, it will be noticed that the deposit of lampblack is only found on that part of the surface against which the issuing gas impinges ; it is not uniformly deposited on the rod, as it would be if the soot were the vapour of heavy hydrocarbons, condensed by its cooling action. It is evident, therefore, that soot cannot be the condensed vapour of those heavy hydrocarbons to which the luminosity of such flames is sometimes attributed, and that Davy's hypothesis was correct. The most conclusive evidence is afforded by the fact, that although luminous flames which are free from solid matter cast no shadow on a white screen when exposed to sunlight, hydrocarbon flames, on the other hand, cast distinct shadows, thus showing the presence of solid matter or particles. Now when the nature of a flame is such that it does not receive enough air, or rather oxygen, to combine with the carbon, it smokes and deposits soot in the neighbourhood. Also by holding a porcelain plate over the flame the soot condenses on it. When, however, a flame receives an abundance of oxygen there is a better combustion, and we may receive also a better light. If we notice the light given by a candle, an Argand and a Bunsen burner, we see the difference in illuminating power, and find that the light and heat given by flames are not proportional—that the hottest flames do not necessarily give or emit much light.

Heat is due to chemical action, while light is generally produced in ordinary circumstances where hydrocarbons are the agents, by the incandescence of solid particles of carbon that are liberated in a flame. In the Bunsen burner we effect nearly a complete combustion at once, and obtain a flame that gives very little light. In an Argand burner we adjust the supply of air, so that, without deranging the combustion, we concentrate it in a smaller space, thereby obtaining a maximum temperature with a maximum amount of light. In a candle we have a sort of "go as you please" combustion, and thus get a smoky flame. It may also be stated that the luminosity of a flame may be increased by increasing the atmospheric pressure, and that an ordinary spirit lamp or flame becomes luminous at a pressure of 4–5 atmospheres, and when supplied with a still higher pressure burns with a smoky flame, showing that the combustion of gaseous matter is less perfect as the density of the atmosphere is increased.

From what has already been said it will be seen that the whole theory concerning the formation of lampblack or soot demands simply two conditions:—

1st. That the substance or material employed should be rich in hydrocarbons, which can be rendered into a gaseous form by means of heat.

2nd. That when such hydrocarbons are burnt, the amount of air supplied should be just sufficient to keep up a dull cold flame, whereby an incomplete combustion is produced by the oxidation of the hydrogen only, thus allowing the particles of carbon that are liberated to pass out of the sphere of the flame and settle elsewhere.

It is one of the characteristic properties of carbon that it unites with hydrogen in various definite proportions, thereby forming a large variety of compounds known as hydrocarbons. Many of these compounds, such as lignite, fats, brown fatty coal, tars, pitches, resins, oils, &c., concern us, as they are used in the production of soot or lampblack. Every mixture of gases require a certain temperature to ignite them; and if this temperature is not obtained the gases will not take fire. We may, therefore, cool down a flame so that it is extinguished, or by partly cooling down a good live flame can make it smoke and give off carbon. This experiment can be easily tried by taking a porcelain plate and lowering it on a flame, and thus cooling it, and we shall find that soot deposits, while the flame also loses its intensity. A certain temperature is, however, necessary in order to obtain soot from a hydrocarbon flame for if the temperature of the flame is lowered below a certain limit we obtain neither light or soot. An illustration of this principle is shown when we place a piece of wire gauze over a flame. By this means we may easily cut off its upper point the unburnt gases being cooled down below the point of ignition. The formation of soot or lampblack is thus easily produced by subjecting hydrocarbons to an incomplete combustion, wherein the hydrogen gas gets oxidised, while the carbon escapes combustion and passes out of the flame. We have also seen that the combustion, when generating soot, must not be so low that these hydrocarbons cannot get decomposed, nor must the combustion be so high that the carbon particles get oxidised and converted into gas. In fact, the quantity of soot produced depends simply upon the regulation of the air that is supplied to the burning matter. We have also seen that we have two ways of collecting the soot; one way by allowing it to condense in chambers, and the other by bringing the flame in contact with some surface—generally a cool one.

No doubt, if condensing chambers were placed in the path of the flue in all our industrial establishments, a large quantity of soot could be caught, and thus a public nuisance abated. Should the draught be hindered by such chambers an exhauster or blower could be used. The soot collected from such factories could be sold as manure, and Hutton says that soot is collected by some people in London and Glasgow for manurial uses, and that it fetches a good market price. The analysis made by Hutton proved that it had really some value as manure, and that it was chiefly exported to the West Indies. For carbon purposes, however, such a material would not be of much value, as it contains too many impurities, unless some cheap process could be devised by which it could be cleaned.

Dr. Köhler mentions that Roberts has calculated the amount of soot that overclouds London on a winter's day to be about 50 tons, and that this figure was confirmed by Sir W. Siemens. He also states that in the ordinary stoves used in Europe 100 kilos. (220lb.) of coal produce about 120 grammes of soot, which seems, on the whole, a very small amount. From these figures, however, we find that the soot escaping in London alone amounts to about 15,000 to 20,000 tons per year.

The author has already stated that the soot manufactured for electric light carbons, &c., is generally made from such raw materials as fats, brown coals, tars, pitch, resins, &c. One of the principal materials used, however, is tar, which is obtained in large quantities either from gas works or petroleum distilleries; in fact, petroleum distilleries have an abundance of this residual matter rich in carbon, which can be utilised in

---

* From Mr. E. T. Carter's "Motive Power and Gearing." *The Electrician* Series.

the production of good soot for carbons. The following table* gives the composition of petroleum (Russian), and is based upon commercial outputs:—

Commercial oils.	Percentage volume.	Specific gravity.	Flashing point in degs. Fahr.
Benzine (light oil)	1·0	0·725	14
Gasoline	3·0	0·775	32
Kerosene (burning oil)	27·0	0·882	77
Soliarovi (lubricating oil)	12·0	0·970	212
Veregenni	10·0	0·890	302
Ordinary lubricating oil	17·0	0·950	347
Cylinder lubricating oil	5·0	0·915	392
Vaseline	1·0	Variable	Variable but high
Liquid fuel	14·0	"	"
Loss in refining	10·0		

Now this liquid fuel is a good material from which to make the lampblack or soot used for high-grade carbons, while the petroleum cokes, of which there are plenty in such distilleries, will serve for second grade goods, electrodes, &c.; in fact, petroleum works could turn their by-products to very good account by establishing a carbon factory. The Budapest petroleum works were considering the subject some time ago, and the project may yet be realised. The author knows that benzine, as obtained by the petroleum distillers in Hungary, has now hardly any value, and that they do not know what to do with it, although some of it is bought for manufacturing the finer qualities of soot from which lithographic and printers' ink is made. Of course, benzine can only be used in water-cooled lamps for making lampblack. If such distilleries are not disposed to manufacture carbons, it would still be to their advantage to produce soot, as they could manufacture that article cheaper than anyone else, with the exception of gas works, where large quantities of tar are also obtained.

The author desires to emphasise the fact that, in burning any material, it is of advantage to use only such substances whose flash points are about the same. If a material is used that consists of a mixture of several substances having various flash points, it will be found that, when such a mixture is burned on a hearth, the lighter oils will volatilise and condense in the chambers where the soot also deposits, and the result is that we obtain what is known as "wet soot," which it is necessary to calcinate before using in a carbon factory. If we use such a mixture of oils in a lamp, we find that the lighter oils will burn away, while the heavy ones will begin to settle around the wick, which gets partly carbonised and clogs. The author made some experiments with Russian raw petroleum some time ago, and constructed a special lamp for the purpose of keeping it cool. He found at first that, with regulation, a good soot flame was obtained, and that only the lighter oils burned away, while the heavy ones, whose flashing points are high, remained behind and clogged up the wick, preventing, after a while, the lighter oils from ascending. At the same time the heavy oils began to char, so that the flame was soon extinguished. We see, therefore, that it is a matter of some importance to a soot factory to use only such substances as have about the same flash points. Lighter oils should be burned in lamps and heavy ones on hearths. No doubt a process could be devised by which a mixture of hydrocarbons of different flash points could be utilised, and that would be by gradually distilling them in some closed receptacle or retort, converting them into gas, and then burning them with suitable burners.

When employing tar as the raw material, it is necessary that it should be free from water, which would otherwise go over and condense in the soot chambers, while at the same time it interferes with the fire. The tar is, in practice, warmed up in tanks, and the water settles at the bottom, and by suitable stop-cocks is let off from time to time. The heating of the tar has also another advantage, and that is it makes it more liquid, depriving it of its viscosity. By these means it is easily led through pipes to the hearth where it is burned. Any old boiler will serve for such purposes. When using oils it is generally unnecessary to heat them, unless they contain matter that may need such heating up. Oils of a low flash point, as has already been mentioned, are generally burnt in lamps, for if burnt on a hearth too much volatile matter goes over. Of course, such oils produce a finer quality of lampblack than tar, and are used for the best printing inks. Tar, however, furnishes as good a soot as can be desired for carbons, and, as it is cheap, it is largely used. Brown coal also gives a good soot, and is used in many soot factories.

As has already been stated, it is very important to produce good regulation of air in a soot works. When a good supply of air is allowed to enter the hearth we obtain free combustion, producing relatively little soot, but one of a fine quality, whereas if too little air is supplied, we obtain more soot, but of a coarser quality. Practice will soon show the amount of regulation that is necessary, and it may be observed that this regulation depends upon the season of the year and state of the weather.

Dr. Köhler gives the following figures relating to the quantity of soot obtained with a given amount of raw material:

100 parts of pitch gives from 12 to 15 parts of soot.
100 ,, tar ,, 15 ,, 18 ,,
100 ,, oil ,, 18 ,, 20 ,,

The soot is of various qualities, and there remains about 50-60 parts of coke, which is used for furnace purposes. Duhamel states that 1,000 kilos. of mineral coal produces about 3·3 kilos. of soot and 400-500 kilos. of coke. Thenius says he received from 400 kilos. of heavy tar oil, 20 kilos. of soot of the first quality, 30 kilos. of soot of the second quality and 20 kilos. of the third and fourth quality. Engler states that in the Black Forest in Germany, where soot is extensively manufactured, they obtain from 100 parts of tar about 25 parts of soot, and from 100 parts of resinous substances 20 parts of soot. Heavy tar oils produce about 25 to 30 per cent. of soot, petroleum about 20 to 25 per cent., and gas from 4 to 7 per cent. The differences given in the above figures are no doubt due to different modes of operations—that is, the different rates at which combustion is forced in different factories. If we take 20 to 25 per cent. as the efficiency of production we shall be on the safe side. In fact, as soot is used in such large quantities in the manufacture of carbons it cannot be expected that its quality should be similar to that used for fine inks, as no doubt such a difference in quality would show very little in a carbon when burning. The main thing is to obtain pure carbon, at a cost of production that will enable the carbon manufacturer to compete with others.

Such hydrocarbons as fat brown coal, tars, pitches, resinous matter and the residuum of oil stills, give us a list of materials that are not expensive and at the same time rich in carbons.

Lampblack, when bought from soot manufacturers, costs about £1. 6s. 7d. or $6.40 per 100 kilos. (220lb.). We can reckon the price of the raw material (tar) from which it is produced at 3s. 4d. or about $0.80 (which is very liberal) per 100 kilos. Taking the efficiency of production at 20 per cent., we should require 500 kilos. (1,100lb.) of the raw material to produce 100 kilos. of soot. This gives us the price of the raw material as 16s. 8d., or $4. The author has calculated that if we add 3s. 4d., or $0.80, per 100 kilos. of soot manufactured as the cost of labour, interest and redemption it is more than necessary. This gives us the price of soot at about £1 or $4·80 per 100 kilos. We see there is thus a saving of at least about 6s. 7d. or $1.60 per 100 kilos. when a carbon factory manufactures its own soot. This is an important item for a carbon factory, and it is hard for those firms to compete who have not their own soot works, as the author knows from experience. We see also from the above figures that petroleum distillers and gasworks have an especial advantage if they would manufacture soot, as they produce plenty of tar as a by-product. Not alone is there a saving in producing one's own soot, but there is also a considerable saving in freight, as soot factories are usually at great distance from carbon works. The author knows of a carbon manufacturer who pays as much as £30 or $144 for a car load (about 10 tons) of soot. The raw material, however, can be procured usually from a neighbouring town, so that the freight will not amount to much.

A few words may be said in regard to the building of a soot factory. It is advisable never to use any wood in any part of the building where the soot condenses, as the hot gases, in passing through the chambers, will so dry the wood that after a time it will become like tinder and fall or crumble to pieces, while at the same time there may be some danger of ignition. One may think that such condensing chambers could be easily and cheaply constructed from sheet or corrugated iron; there are, however, some facts that have to be taken into consideration. In the first place it has been found that soot settles best on rough surfaces, the deposit taking place like snow. Small particles of soot settle on a surface, and after a time, are formed into flakes, the size of which increases so that they get too heavy to sustain their own weight and fall down. Of course, some of the soot adheres to the walls, and these are also scraped from time to time with a sort of wooden hoe.

When the condensing chambers are constructed of iron, the soot cannot settle well on the smooth sides, for each flake is composed of several very small particles, which, if they do not settle, will be taken by the draught up the chimney and so escape. Then again, iron being such a good conductor of heat, water and other vapour would easily condense within such chambers, whereas the object in soot making is to have chambers that are always so warm that volatile matter will not easily condense, but will escape by the chimney.

The best, the most practical and economical method is to build the chambers simply with common rough bricks, the sides of which offer a favourable depositing place for the soot. The walls of such condensing chambers should in no circumstances be finished by coating them with plaster. Such a coating would lessen the efficiency of the depositing surface, while at the same time, when the hot gases circulate through, the plaster may crack and fall down and contaminate the soot. A common unfinished chamber of bricks set in good cement is all that is necessary. The best flooring to give such chambers is flagstones solidly and evenly laid, while the interstices should be partly filled with good cement, in such a way that there is no danger of dislodging such cement when the soot is scraped out; in fact, the scraping of the soot together should only be done with wooden implements somewhat similar to hoes.

It will be noticed that a factory will generally produce a much better quality of soot after it has been working for some months. This is due to the fact that in the first months of operation the moisture that is in the walls is driven out by the heated gases. This moisture cools the gases, thereby interrupting the draught and lessening their velocity, which causes the material in the hearth to burn without flame, and permits some of the unburnt products to escape and settle in the condensing chambers, where it and the moisture get absorbed by the soot.

However, after the condensing chambers have been well dried, it will be found that they keep their heat well, and that the quality of soot obtained is much better. In starting the fires at the hearths, they should be permitted to have all the air that is necessary for complete combustion, and at the same time it is advisable not to start too large a fire in the beginning, so that a gradual draught is established while the chambers are slowly heating. After a while, when a good circulation is obtained, we can commence by regulating the damper of the chimney so that the flames have a sort of dark, red, smoky appearance, while the smoke issuing from the chimney should have a light appearance—that is, no dark, black smoke should appear there. Fuel should be supplied to the fire often but little at a time. Care should also be taken that the supply of air be not so decreased that the combustible begins to swell up, as this may allow unburnt matter to escape. These unburnt gases may cause an explosion by mixing with unburnt air and soot. However, under normal conditions no explosion can occur. The fuel must always be supplied gradually, and not too much of it at a time, and care should also be taken when igniting the fire at the commencement. When it is desired to discontinue such fires notice should always be taken before leaving that no combustible remains on the hearth. With such simple precautions and a well regulated service everything will work well. Soot factories generally work day and night, with the exception of one day or two in the week when the chambers are allowed to cool and the soot is collected and removed.

CHAPTER XV.

SOOT FACTORIES.

Formerly soot was produced on a very simple scale by heating resinous substances in an iron pot and then igniting the vapours. Fig. 68 represents an old-fashioned soot factory,

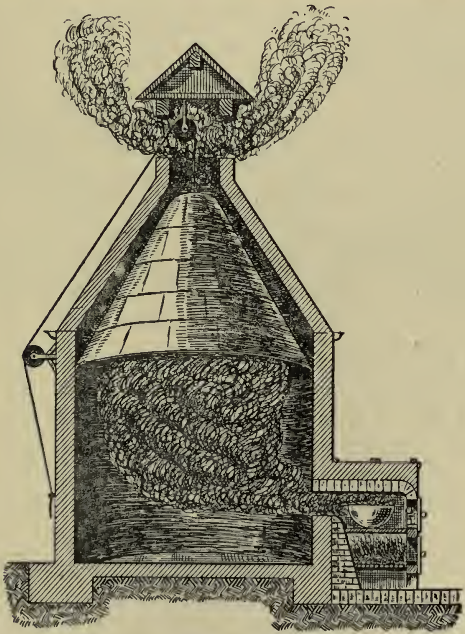


Fig. 68.—Primitive Soot Factory

and it will be seen that the iron pot containing the hydrocarbons is simply placed on a hearth, which is heated by a fire underneath it. The smoke of the ignited vapours is allowed to pass into a chamber in which a large cone made of coarse cloth is suspended, which offers a favourable depositing surface for the soot. The base of the cone was generally made as large as that of the chamber itself, so that when it was lowered by means of the rope and pulleys shown, it would, at the same time, scrape off what soot there was on the sides of the walls. At the apex of the cone there was an opening through which the smoke passed out into the air, and it will be seen that, the smoke having so small a path to travel, much of the soot naturally escaped. The cloth of which the cone was constructed was also soon charred and fell to pieces. In fact, the whole process was a very uneconomical one. Sometimes a long building was constructed, in which four or six such cones were suspended, each having an outlet, and this was in some degree an improvement on the single cone system, as it produced various qualities of soot, the soot collected at the cone nearest the fire being of a lower quality than that collected at the cone farthest away. Also, as there was a larger surface and various paths for the smoke to travels there was a much larger output.

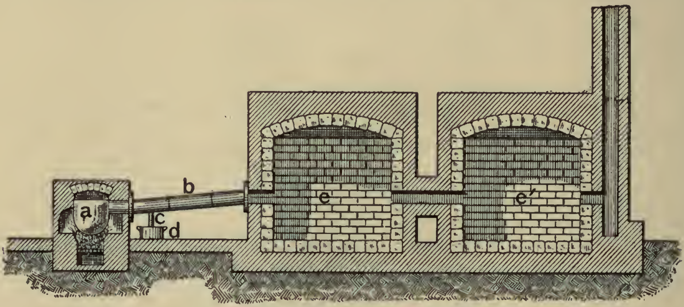
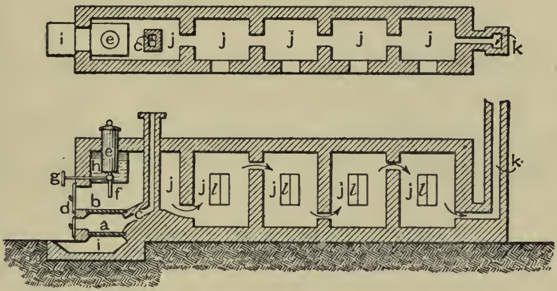


Fig. 69.—Primitive Chamber System.

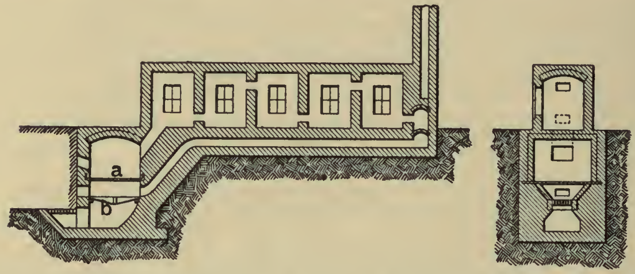
As the demands for soot increased and competition arose it was found necessary to make improvements, and we find that the principal of the chamber system soon received notice. In Fig. 69 we have a representation of one of the early plant, that had condensing chambers. The iron pot containing the resinous or other substances is shown at *a*, which is heated from a fire built underneath it. The sooty smoke passes the sheet iron pipe *b*, while a small branch pipe *c* served the purpose of draining any volatile matter that condensed, and which was led or collected into the vessel *d*. The smoke, after leaving the pipe *b*, passed into the chamber *e*, and then by way of a small canal into the chamber *e'*, from which it entered the chimney as shown. It will be noticed that we have here a decided improvement upon the system that was operated with cones of cloth. The chambers *e* and *e'* were solidly built of stone, which retained the heat well, and the smoke had to travel a longer distance, so that a larger deposit of soot was obtained, while at the same time provision was made for condensation of volatile matter. Upon this principal, more or less, modern soot factories that use hearths are built, the difference being that more and larger chambers are used and better devices are employed for the regulation of the air, &c.



FIGS. 70 and 71.—Soot Factory for Liquid and Solid Fuel.

A soot factory with more chambers is described by Thenius in his book, entitled "Werwerthung des Steinkohlentheers." This factory was built similar to that shown in Figs. 70 and 71, of which one is a ground plan and the other a cross-section view. Here *a* is a separate furnace by means of which the cast-iron plate of the hearth *b* is heated, while the admission of air is regulated by a sort of sliding damper that is placed in the door *d*. The fuel, which may consist of oil or tar, is placed in the reservoir *e*, from which it is allowed to flow or drop into the hearth *b* by means of the cock *f*, which is regulated at *g* as shown. It will also be seen that this reservoir is placed in a water tank *h*, so that it cannot be over-heated or cause the liquid fuel to boil over. The fuel in dropping on to the heated cast-iron plate of the hearth is converted into vapour, which is ignited while the smoke or soot passes from one chamber to another, as shown by the arrows. The ashes from the fire at *a* fall into the ash pit *i*; *c* is the chimney for this pit. The chambers *j j* are provided with iron doors *l*, while the smoke, or hot gases, &c., pass out at the chimney *k*. Such a factory can use also solid fuel, which is placed in the hearth *b*. When using liquid fuel, it should be constantly fed in a spraylike fashion.

It will be noticed that communication between the chambers is alternately effected by means of openings or small windows placed at the top or bottom in the partition walls, thus affording a longer path for the soot smoke to travel. There is also a damper at the chimney (not shown), by which regulation of the draught is also effected.



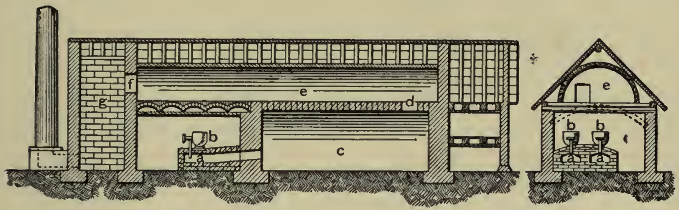
FIGS. 72 and 73.—Longitudinal and Cross Sections of Soot Factory for Solid Fuel.

Two views of another neat design for a soot factory are shown in Figs. 72 and 73.* Such a factory is, however, as will be seen, only intended to use solid material for fuel. The resinous or other matter is simply thrown on the iron hearth *a*, which is heated by the furnace *b*, as shown. The sooty smoke passes from one chamber to another in the manner already described. Judging from the size of the hearth and chambers, it seems that the latter are, on the whole, much too small, and that a second floor could be added with advantage, as it has always been found best to force the sooty smoke to travel a long path, in which it has frequent opportunities to settle or deposit.

---

* Dr. Köhler, "Die fabrikation des Russ," &c.

Figs. 74 and 75* illustrate a soot factory as generally built in the Bavarian Black Forest, where there exists quite a large industry in this branch of work. The hearth is represented by *a*, into which the material is thrown when it consists of such solid matter as pitch, resin, &c. When liquid fuel is used, such as tar, oils, &c., they are poured into the receptacle *b*, which is placed above the hearth, and from here it is allowed to flow into the hearth by means of a pipe that is provided with a stop-cock, as shown. When starting the fires sawdust, shavings, or other waste is saturated with tar and then lighted, after which the fuel is constantly supplied. The sooty smoke enters first into what is called the cooling chamber, shown at *c*, and from here it passes into the chamber *e* by way of the opening at *d*. From the chamber *e* it passes through *f* into the tower *g*, which is divided into two parts by means of a wall, and then out at the chimney that is provided with a damper for regulation. The chamber *e* is usually about 18–20 metres long and about 5 metres wide at its base. It will be noticed that the path the soot and gases are forced to travel is a long one, so that there is ample time for the soot to settle. Then again there is a span of coarse cloth that covers one of the tower chambers through which the gases have to traverse in order to get into the chimney. This cloth catches up the soot which had not settled in the chambers, which is thus prevented from escaping. Of course the cloth must be often shaken or the soot will clog up the meshes of the cloth and interrupt the draught. It requires frequent renewal, as the heated gases soon dry up the cloth, and it falls to pieces. The cost of these renewals is, however, only trifling. In fact, it would be an



FIGS. 74 and 75.—Typical Bavarian Blackwoods Soot Factory.

---

* Dr. Köhler, "Die fabrikation des Russ," &c.

easy matter to construct a mechanical shaker, which would work either continuously or periodically. Dr. Köhler mentions that these simple furnaces work very regularly, giving a large output of fine quality soot that is in great demand. In the Black Forest the factories work continuously, with the exception of a day or two from time to time, during which the chambers are allowed to cool down. At this time the soot is collected and stored in the rooms at the back of the condensing chambers.

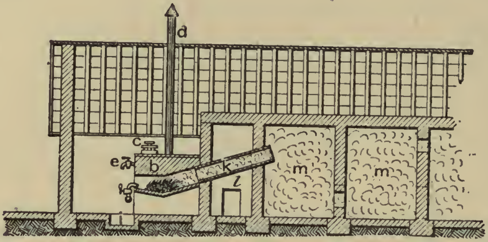


Fig. 76.—German Soot Factory. Longitudinal Section.

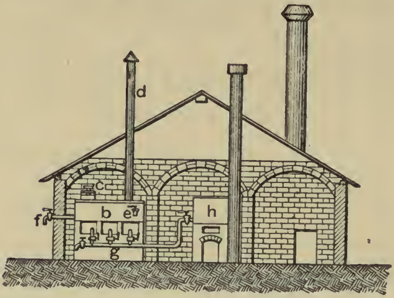


Fig. 77.—Section of German Soot Factory.

Up to the present only factories have been shown having hearths where no contrivance exists by means of which the flames are cooled down a little. This is not necessary, as it has been shown that the Blackwoods factories work well, although they are furnished with no such coolers. There are, however, some manufacturers in other parts of Germany who favour the placing of a tank or kind of boiler over the hearth, so that some of the heat given out by the flames may get absorbed by the water contained in these boilers. Such a factory is shown in Figs. 76 and 77, which Dr. Köhler says gives entire satisfaction, although it cannot be proven that the soot produced is any better than that manufactured in a factory without a boiler. The hearth of this factory is so constructed that it can be used for either solid or liquid fuel. In Fig. 76 *a* represents a V-shape cast-iron plate, the form of which prevents any liquid or melted fuel from running out, while the incline at the back affords an easy way for the gases to escape. A wedged-shaped tank or boiler *b* is placed over the hearth. This tank is made of sheet-iron about 6mm. thick, and is provided with a suitable manhole at the top *c*, while the pipe *d* takes off the steam. On the front side of the tank there is a stop-cock *e*, which serves as a gauge, as the water contained in the tank should not be allowed to sink lower than this position, while another tap *f* serves for an occasional blow-off.

By means of piping *g* having at least a diameter of about 2½in., tar or oils (heavy ones) are lead from the tank *h* to the hearths as shown. At each hearth there is a branch from the piping having a stop-cock, enabling the quantity of fuel supplied to be regulated, and if solid fuel is supplied these cocks can be turned aside. The fire door of each hearth contains an air regulator that permits of any adjustment. The liquid fuel in the tank, if very thick, is usually heated by a gentle fire built in the small furnace underneath the tank, which thus reduces the viscidity of the tar, &c. The coke that is formed in the furnaces or hearths is from time to time raked out and thrown into the pit *i*, which also contains some water. There is a canal or pipe *k* made of light sheet iron, about 3·5 metres in length, with square cross-section. This pipe leads the soot, smoke and gases into the chambers *m m* in a manner similar to other works already described. The canal passes through the chamber *e*, which is opened and exposed to the air, and hence called the cooling chamber. Any excess matter settles in the pipe *k* and flows back into the hearth.

The chamber system in this factory consists of three rows of parallel chambers, each row about 36 metres in length, so that the soot smoke has to travel about 100 metres before it reaches the chimney. The chambers communicate with one another through openings that are placed alternately near the bottom or top of the dividing walls, while iron doors between each chamber furnish means of cleaning out or collecting the soot, which takes place once a week. It is stated that such a factory as this consumes about 500 kilos. of tar, &c., per day in a hearth, from which quantity of raw material we may reckon a production of 100 kilos. of soot. The cooling tank *b* may also serve for other purposes, as for heating water that can be used for the steam boiler in the carbon factory, if near by.

It is obvious that in producing soot for electric light carbons, a much larger number of hearths must be used than in a factory such as that just described, as for such products about 1,000 kilos. of soot daily is required by even medium-size carbon works.

When bituminous brown coal is used as fuel a simple grate furnace can be used, and this material produces a very good soot, and, in certain localities, is one of the cheapest raw materials to be obtained.

One point to be noticed in connection with soot factories is the filtering of the smoke before it passes out at the chimney. Although we may force the smoke to take a long path before it reaches the end chamber, flakes of soot will nevertheless escape into the air, causing loss in production, and this in some factories amounts to quite a large percentage of the total output. One method of preventing such an escape is, as has already been mentioned, by spanning some coarse cloth over the mouth of the last opening that leads to the chimney flue. This method is a good one on the whole, requiring, however, frequent shaking and renewal of the cloth. Sometimes the cloth gets so clogged up with soot that shaking has no avail, as the soot flakes get into the meshes and cannot be effectively dislodged. With care and precaution this method works well. Wire gauze has also been substituted for cloth, but this material also soon gets clogged up so that shaking is of no avail. A simple remedy here would be to have a double set of such screens, interchanged at regular intervals. The screen withdrawn from action could be cleaned by means of a bristle brush. A still better method would be to have a revolving screen of wire gauze, on which a bristle brush would bear, the cleaning thus going on constantly. Such a device, or something similar, could easily be constructed, while the power necessary to drive it would be very small. Dr. Köhler says that a "blind" device, as shown in Fig. 78, has given much satisfaction. It is constructed of sheet-iron, with a surface of about 1 sq. metre, while the parts forming the blind are about 50cm. broad, and can be adjusted into any position or incline by means of the handle *a*. The action of this device is as follows:—The soot, smoke and gases when they arrive have the direction shown by the single arrow. In passing through the blind the soot flakes fly against its sides, which, as shown, are in an inclined position, and thereby get their direction deflected so that they take the downward course and fall on the floor, while the gases take the upward direction leading to the chimney flue. On the whole, this device seems likely to succeed, and it would be well to place such a blind at every opening that connects one chamber with another, thereby lessening the chances of the soot getting as far as the last part of the building that leads to the chimney flue. Of course, this device would also require a little shaking occasionally, and this is effected by means of the handle *a*.

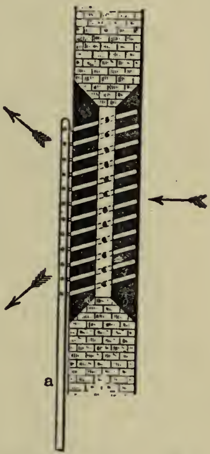


Fig. 78.—Blind used for Deflecting Soot.

No doubt a soot factory could be designed on more modern lines. One that would work continously is required, realising a larger output per plant. The lines on which such a factory could be built would be somewhat similar to Mendheim's chamber system as described in the chapter on furnaces. By means of dampers and a side canal, a soot chamber could easily be switched out of the working circuit and emptied. In this way the soot from all the chambers could be successively cleared without interruption, as only one chamber would be switched out and in at a time.

Very fine qualities of soot are produced by burning oils or gas, and Fig. 79 represents an old-fashioned way, but one which is still largely used in practice, where oils are burned for producing the soot from which the finest engraving and printers' ink are made. From the fact that soot is manufactured by the aid of lamps, we obtain the name "lampblack." It is said that the Chinese have for ages produced lampblack obtained by burning camphor in lamps, allowing the smoke to strike some cool surface, and that the lampblack thus produced was used in the manufacture of what is known as Chinese ink.

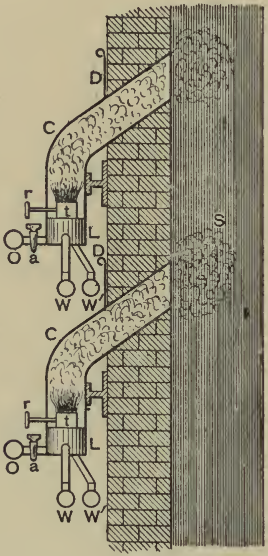


Fig. 79.—Lamp System for producing Lampblack.

In Fig. 79, L represents the body of the lamp, which consists simply of a flat tube, *t*, in which the wick is placed and regulated by the wheel *r*. This tube is connected at its lower end to a small pipe which branches off from the main feed-pipe O, which is connected with a reservoir that contains oil or some other liquid hydrocarbon. By means of a small cock, *a*, the oil fed into the lamp can be turned on and off. The body of the lamp is not made larger, because it is not desired to have a large quantity of oil, &c., near the flame of the lamp, nor is it necessary, as the oil feeds constantly from the main pipe. Another safeguard is the fact that the whole lamp is enclosed in a water-tight case, through which water runs slowly; W represents the water feed-pipe and W′ the drain pipe, both pipes being connected with the cooling case by rubber tubes. In this manner the lamp and oil are always kept cool—a necessary condition for making lampblack. Over the case of each lamp there is a funnel, C, made of sheet-iron, which leads into the soot-condensing chamber S, which may be built in the manner already described, and the size of which, of course, depends upon the number of lamps producing soot. The lower part of these funnels contain sliding dampers, regulating the quantity of air admitted. A small, tight-fitting sliding window is attached at the front part of the funnel, permitting the renewal of wicks or occasional cleaning as required. At D there is a damper that can be let down, and closes the passage leading into the condensing chambers when the lamp is not working.

It is obvious that oils or liquid hydrocarbons, when burned in lamps, produce a much finer quality of lampblack than when burned on a hearth, as the flame of each lamp can be regulated to a nicety—a condition which cannot be secured with a hearth. Then, again, we have in the lamps an easy means of keeping the burners and oil cool, which prevents volatilisation, securing the production of a dry soot of good quality. When oils, &c., are used that have a low flash point it is not necessary to employ wicks in the lamps, as such oils will burn well by simply having a flat, cup-like plate at the top of the tube in connection with the feeding pipe. It is advisable, however, when working without wicks, to have the cup directly over the cooling case, so that it will not get hot. It is also well to have an oil catcher underneath each lamp to catch up any overflowing oil. As shown in Fig. 79, two or more rows of lamps can be placed on a wall, so that where even a large number are used no large amount of room is taken up. It is advisable to keep the oil reservoirs in a separate room to avoid danger from fire.

The manner in which the pipes and reservoirs keep and retain the same level of oil is shown by Fig. 80, where O O′ are pipes that lead to the different rows of lamps, while A A′ are their respective reservoirs. At B we have an air-tight reservoir. When the cock *b* is closed no air can enter or leave, and the oil will only flow out at the pipes *d* and *d′* when the level of the oil in the reservoirs A and A′ has sunk below the lower ends of the pipes. As oil flows out of the pipes *d* and *d′* air enters, and when the level in A or A′ rises up to the lower end of either pipe the discharge stops. By this means the level of oil can always be kept the same with but little attention. When the reservoir B has discharged nearly all its oil it is filled by closing for a moment the cocks *a a′*, and opening those at *b* and *c*. When B is filled the cocks at *b* an *c* are closed, and those at *a a′* opened again. The arms or pipes *d d′* can be made to turn, so that any desired level can be obtained in the reservoirs A and A′.

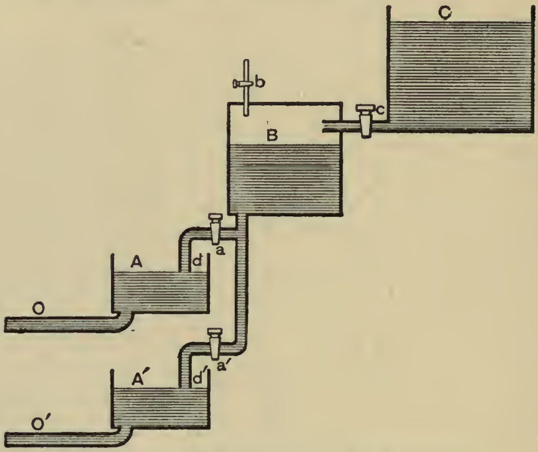


Fig. 80.—Reservoir System for Feeding Oil, &c.

A soot or lampblack lamp, designed by the author, is shown in Fig. 81, where A represents the lamp when in working order, and B gives a view when the funnel is pushed back in order to clean or renew the wick. The pipes *w w* are those connected with the water mains, in order to keep the lamp and oil cool, while the oil fed to the lamp is conducted from the main pipe to the one shown at O in A. The other parts of the lamp need no explanation, as they will be clearly understood from the drawings.

Among the many mechanical devices used for producing the finer and best qualities of lampblack, nearly all are based upon the principal of allowing a flame (obtained by using oils or gases) to strike upon some cool surface on which the soot of the flame will deposit. These devices usually rotate, and have scrapers that take off the lampblack, which falls into reservoirs, while the cooling is effected by means of water. Prechtl's apparatus consists of a long hollow cylinder or drum made of cast iron, which revolves slowly, while the flames from a battery of lamps or burners, which are placed underneath this cylinder, strike it, causing a deposit of lampblack, while a leather brush rubs on the surface and scrapes off the soot which falls into a receiver. The drum is kept cool by allowing water to flow through it slowly. The outer surface of the drum is protected by a guard made of sheet-iron, having

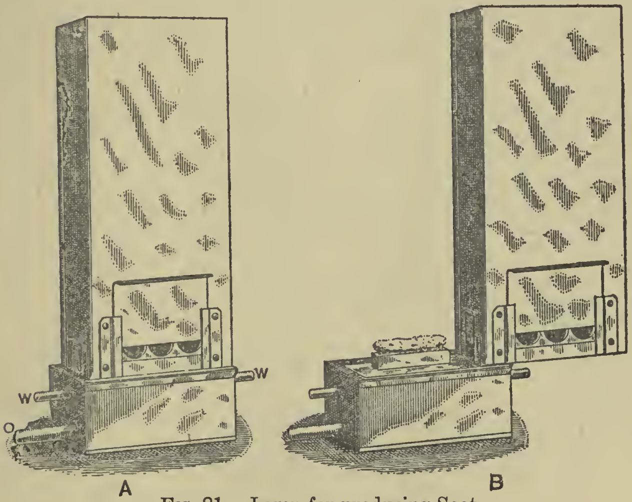


FIG. 81.—Lamp for producing Soot.

a clearance of about 1in., and the lampblack is thus prevented from flying off or escaping. The apparatus of Shaemaker, of Edinburg, Pa., consists of a right-angled hollow cone, through

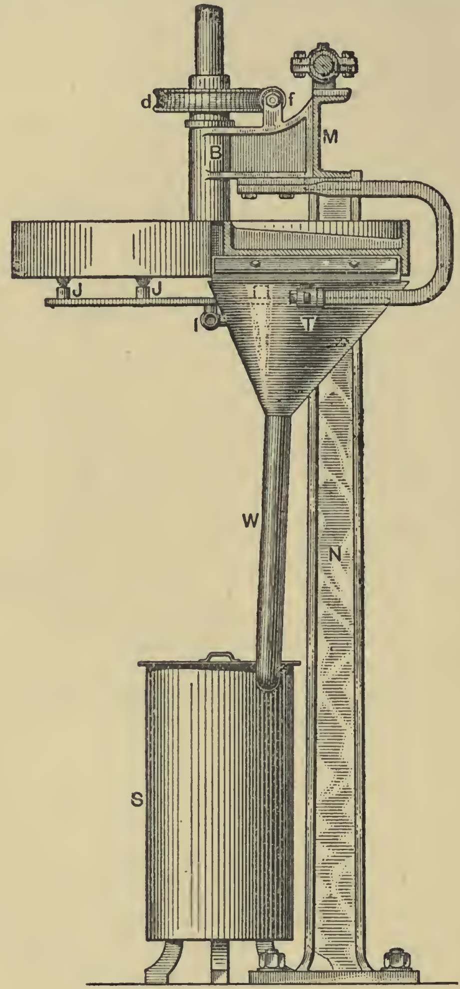


FIG. 82.—Thalwitzer's Apparatus.

the apex of which a shaft is attached, which is caused to revolve in an inclined position, making an angle of about 45deg. with the horizontal plane. On the inner top side of this cone the flames strike and cause the deposit of lampblack, while on the other side a scraper takes it off. Water is allowed to flow on the outside of the iron cone for cooling purposes.

Many similar machines exist for the production of lampblack, and one of the best on the market, and the one that is generally used in Germany, is the apparatus designed by Otto Thalwitzer, associated with the firm of Biermann and Co. This firm use gas which is obtained by the distillation of heavy mineral oils, and employ about 150 machines of the Thalwitzer type. Fig. 82* represents a complete Thalwitzer machine, and Fig. 83 shows a cross section of the working parts. Originally the machine was constructed to produce lampblack directly by burning oils, but, as the demand increased for a very fine quality of lampblack, he adapted it for gas, which, as already mentioned, is produced by distilling oils.

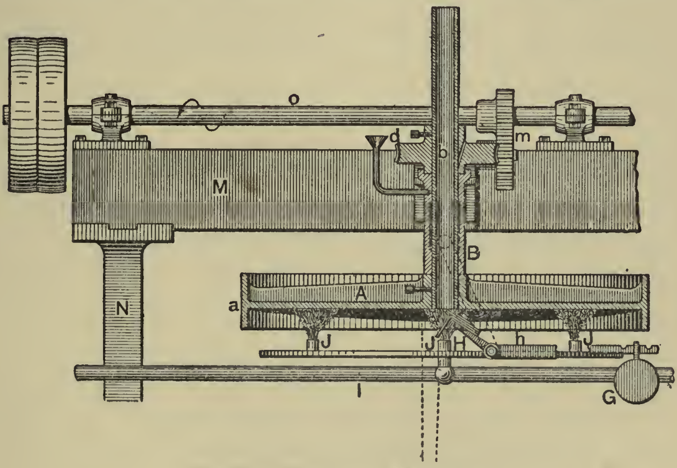


Fig. 83.—Thalwitzer's Apparatus.

In Fig. 83 A represents a cast-iron plate of about 80cm. diameter, constructed with a flange *a*. The upper part acts as a reservoir for the water, and the lower part protects the flames from draught. This plate revolves slowly, being con-

---

* Produced by special permission of Mr. Thalwitzer.

nected to a hollow vertical shaft shown at *b*, which serves at the same time to conduct the products of combustion outside of the working room and into the air. This shaft is held in position by the bearing B, and at its upper end (Fig. 82), by means of the worm wheel *d* and worm *f*, it is caused to revolve. The bearing B is attached to the iron part M, on which a whole row or set of similar apparatus rests, all driven by the shaft O, to which wheels (as shown at *m*) are attached which work the worm *f* of each apparatus. The part M is supported at intervals by pillars, as shown at N. The working of this apparatus is as follows: Water is always added to the upper part of the plate A in proportion as it evaporates, and thus the water on the revolving plate is always at a temperature of about 100°C. The object in keeping the plate at this temperature is to prevent the deposited lampblack on the other side of the plate from absorbing any of the products of distillation or combustion. As will be seen from the drawings there is a row of burners under the plate at J, which are fed from a common pipe *l*, while the scraper H, which is held by the arm *h*, can be regulated by shifting the weight G. The lampblack, as it is scraped off the revolving plate, falls into the funnel T, and from there into the sheet-iron receiver S, shown in Fig. 82. Mr. Thalwitzer says that such an apparatus consumes about 8 cubic metres of gas per 24 hours, and produces from 700 to 1,500 grammes of lampblack, while, when using oil direct, an fficiency of about 20 per cent. to 25 per cent. of the weight of oil consumed is obtained as lampblack.

Although the process of manufacturing lampblack from gas, as here described, is not very well adapted for the production of raw material for making electric light carbons, &c., on account of its cost, especially on the Continent; yet when gas (natural) can be obtained at low cost, as in some parts of the United States and Russia, such a process can be easily worked, and an abundant quantity of soot can be produced by using machines as here described, with some slight modifications to lessen cost of working.

In the same manner as water power is attracting attention everywhere, and is being economically utilised, so will soon the large wells of natural gas, which abound in the United States and Russia, attract attention. It is, of course, the fact that in some parts of the United States natural gas is used, as at Pittsburg, &c., yet there is much room for development. There could be no more ideal position for an electric light carbon factory than in the natural gas regions of the United States. The gas serves for heating the boilers that supply steam to the engine, which provides the power necessary to run such a factory; it serves also as fuel for the furnaces for carbonising the carbons, electrodes, &c.; and it serves for the production of lampblack from which the highest grade of carbons, &c., can be made.* Such a factory could also manufacture printing inks, blacking, &c., and it is the author's desire that this book may show a way for the creation and establishment of such profitable industries.

---

* At the Acetylene Congress held in Budapest lately, one of the members read a Paper on the production of soot from acetylene. It is claimed that soot so produced is of the purest and highest grade, and that when calcium carbide becomes cheaper it will surely also be used in making soot.

APPENDIX.

American Method.

Although it was the author's intention only to describe and explain the art and process of making high-grade carbons in the manner they are manufactured in Europe, a short description of the American process of making the common copper-plated carbons will no doubt be interesting to the reader. In a Paper read before the Canadian Electrical Association by Mr. Fisk some time ago, he says:—

Twenty-five per cent. of gas coke, mixed with 75 per cent. of petroleum coke, is said to make a good carbon for low-tension work. The petroleum coke is a by-product of the oil stills, and is the only kind used to any great extent in the manufacture of carbon points for the electrical industry. It is of primary importance that the coke, and, in fact, all the ingredients used, be absolutely free from impurities. The other constituent of our carbon is pitch. This is made from coal tar, which is a by-product of gas retorts. It may also be obtained from blast furnaces, but this kind is more or less contaminated with iron, and, therefore, is unfit for this class of work. Pitch for this particular purpose is difficult to obtain, as the makers do not care to expose their still to the high temperature necessary to drive out all the oil and reduce it to the proper specific gravity; and it is more or less "wet," as the men in the factory say.

The first step in the process of manufacture is that of crushing the coke. This is accomplished by means of a machine in appearance like a mammoth coffee mill. The coke comes from this crushed to about the size of coarse gravel. It is then automatically elevated to a large bin in the upper part of the factory, and from thence is conveyed to a large iron hopper situate directly over the calcining retorts. Into these the granulated coke is conducted by means of spouts with gates arranged to control the flow of material into the several retorts. These retorts are then sealed up, thereby preventing combustion, with the exception of a few vents to allow of the escape of gas, arising from the heating of the coke to a state of incandescence, which point is reached in from 24 to 48 hours after firing. After this, if the coke is not pure it will be found to have caked, necessitating in some cases the use of bars to break it up sufficiently to allow of its being drawn from the retorts. If pure it will appear crisp and dry, and to have suffered a loss in weight of about 30 per cent. After the retorts have been drawn sufficiently long to allow of cooling, their contents are "elevated" to the milling department, and run through a set of French burr stones encased in iron, very similar to a grist mill chop stones, then through a silk bolter for separating the coarse from the fine; the former returning to the milling machine, the latter being conveyed to bins with suitably arranged spouts over scales, from which it may be drawn and weighed as required by the mixing department.

We will leave the coke here for the present, and return to the other ingredient, namely, the pitch. This is dense, hard, solid, very brittle and dry, and in appearance somewhat resembling gutta-percha. This material, when it reaches the factory, is encased in casks, holding about 600lb. each. It is broken up by hand labour into a convenient size for handling, and then subjected to a granulating process similar to that of the coke. Finally it reaches a spout close beside the one from which the coke can be drawn.

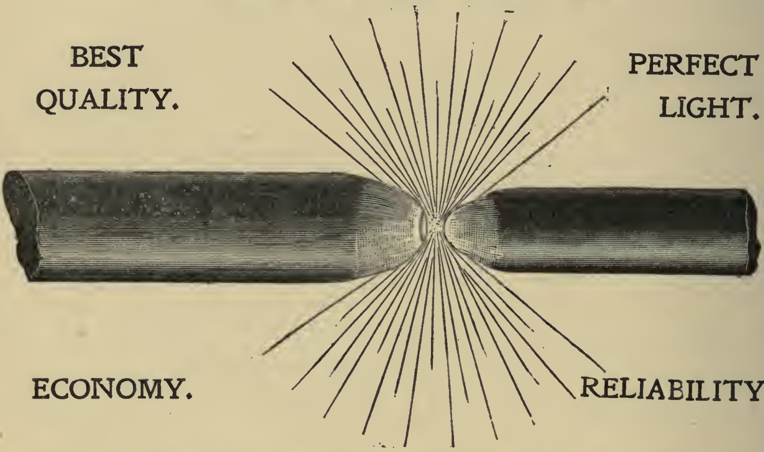
We have now followed the two principal ingredients through the various processes which were necessary to prepare them for the mixing room. It is, I am told, upon the manipulation of the material at this stage that the success of the future carbon greatly depends; in fact, the great secret lies in the mixing. We can better understand the skill and care required to properly amalgamate the mixture when we learn that each particle or grain of coke must have its individual coating of pitch, and it will be interesting to learn that this coke is ground so fine that a grain magnified a thousand times would only appear the size of a shot. To obtain these results the materials are carefully proportioned by weight, and then placed in a mixing barrel. This is a rotating cast-iron cylinder, within which, in the same direction, an independent shaft revolves twice as fast as the cylinder, to which are attached arms so arranged that every part of the barrel is covered or swept in each revolution. This is again attached to a furnace in such a way that the flues follow the whole circumference of the barrel, maintaining a uniform temperature of about 300°F., which is necessary to bring the pitch to a state sufficiently plastic for amalgamation. Thirty minutes is the time required for each batch, which would make about 1,600 carbons.

From this machine it is taken to the cooling room, and spread out for 10 or 12 hours to cool. Here the mixture solidifies to such an extent that it becomes necessary to pulverise it again to perfect it for the moulds. This end is attained by means of a mill, the pulverising feature of which is two discs, 30in. in diameter, with corrugated face plates about one one-hundredth of an inch apart, revolving in opposite directions at the rate of 1,500 revolutions per minute. From this it is once more passed through a bolting machine, and then, finding its way down gravity tubes to a bin on the floor below (which is the moulding room), it is carefully weighed out by workmen on peculiar little scales with clock-like dials, in quantities just sufficient to fill each mould as it comes hot from the oven.

The mould, having been previously lubricated with some heavy oil, is now ready for its charge, which the operator places in it, and works evenly over the whole surface with a spatula to ensure uniformity of density. The cover, or top half, is placed in position, and the mould and its contents pass for a few moments into an oven, the temperature of which is about 300°F. As soon as the mixture becomes quite adhesive the mould is placed in the hydraulic press, and then subjected to a pressure of several hundred tons.

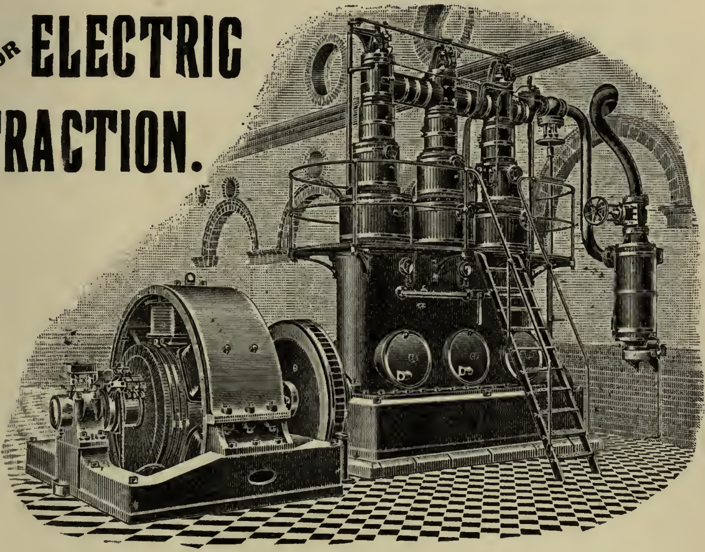
The mould is now removed and opened, and we have a corrugated card containing 16 or 18 carbons, each one being joined to its neighbour by a fin, which is inevitably formed when subjected to the enormous pressure before mentioned. These cards are placed on plates which are fitted to receive them perfectly. These plates, with their contents, are piled up, and weights placed upon them to prevent warping. When cool they are broken apart, gauged for size, culled, and the fin scraped off. They are then laid in the furnace for baking. This furnace is rectangular in shape, 34ft. by 11ft., 4ft. deep, and made of fire-brick, and is similar to a large vat set about two-thirds below the surface of the earth. Over this, when filled, is placed a dome-shaped cover, sufficiently high above the sand and tile which cover the carbon to allow of a free passage of the flames, and which is continued by flues back through the sides and also underneath, thus completely enveloping the body of the furnace in flames. The carbons are carefully placed in the furnace and separated from each other with washed sand, which is brought from the shores of Lake Ontario. Some days are required to completely load a furnace, as each section will hold about 75,000 carbons.

The cover having been placed in position and sealed with fire-clay, the fire is now started, crude oil being the fuel used, as well as in the case of the retorts and moulder's oven. The fire is continued moderately for 48 hours to allow of the gas escaping without blistering the carbon. It is then forced to its utmost for from 48 to 60 hours longer, then shut off, and the whole allowed to cool for 48 hours before uncovering. The top, which is mounted on wheels, is then rolled off, and a few carbons, taken from various parts of the furnace, are tested by a Wheatstone bridge and galvanometer for resistance, as this at once determines if the baking has been carried sufficiently far. If the measurements of all the samples exceed four-tenths of an ohm, the furnace is re-covered and fired for some hours longer, but this very rarely has to be done. If the resistance of the samples shows that the contents of the furnace have been sufficiently baked, it is unloaded, the hot carbons being handled with forks. When cold, they are sorted, the firsts and seconds being easily determined by rolling on level steel plates. After this inspection, they are ready for the plating room, where they receive their copper coat by being hung in leaden vats containing a saturated solution of sulphate of copper. These vats, of which there are several dozen, are connected in series with a 20-ampere constant-current dynamo; 20 to 30 minutes is the time required to complete this plating process. The carbons are then washed in hot and cold water and placed on racks to dry, after which they go to the packing department and are ready for use.



GENERAL ALPHABETICAL INDEX.

INDEX TO ILLUSTRATIONS.



Standard
Books & Publications

OF

"The Electrician"

PRINTING AND PUBLISHING COMPANY, LIMITED,

LONDON.

May, 1916.

CATALOGUE

OF

SELECTED STANDARD

ELECTRO-TECHNICAL BOOKS,

- - - COMPRISING - - -

"The Electrician" Series

AND OTHER WELL-KNOWN BOOKS.

LONDON:
"THE ELECTRICIAN" PRINTING & PUBLISHING Co., LD.
1, 2 & 3, SALISBURY COURT, FLEET STREET, LONDON, E.C.
And all Booksellers at Home and Abroad.

VALUABLE WORLD-WIDE ADVERTISING MEDIUMS.

Rates free by Post on Request.

"THE ELECTRICIAN."

Every Friday morning. Price 6d., post free 7d.; abroad, 9½d., 1 fr., $0.20

TERMS OF SUBSCRIPTION:	YEAR.	HALF-YEAR.	QUARTER.
Great Britain	£1 8 0	£0 14 6	£0 7 6
Canada	1 9 6	0 15 0	0 7 6
Countries in the Postal Union	1 10 0	0 16 0	0 8 6

Bound Volumes (*April and October*) 17*s*. 6*d*. *each, post free* (*U.K.*) 18*s*. 6*d*. *; abroad* 20*s*.

"THE ELECTRICIAN" is the oldest electrical *journal* published. First series, 1861; second series, 1878. It has always borne the same title, been the same size, and been published weekly. Consequently the Volumes form a unique set of uniform appearance. In the volumes of "THE ELECTRICIAN" will be found the most valuable collection of original Papers and articles by nearly every leading writer on every branch of electrical engineering, science and industry, besides all Papers read before the principal Electrical Institutions throughout the world by men eminent in the Electrical Profession, and authenticated reports of the discussions thereupon. Original articles appearing in "THE ELECTRICIAN" are written by gentlemen having no interest whatever in particular electrical systems, and with but one object—the advancement of electrical knowledge and electro-technology generally. Many of these original series of articles have since been revised and amplified, and published in book form. These form the nucleus of the well-known "ELECTRICIAN" SERIES.

Much space is devoted to illustrated technical descriptions of the Electricity Works and Electric Railways and Tramways, and in the very full record of Municipal Notes the progress and development of Municipal Electrical Enterprise is given. The Municipal Notes of "THE ELECTRICIAN" are more numerous, complete, and up-to-date than those of any other technical or trade journal.

In addition to the above, "THE ELECTRICIAN" contains a complete record of all the legal causes which have occupied the attention of the Courts of Justice for the past 39 years. It is customary for "THE ELECTRICIAN" to occupy a prominent position in the Courts as an authority upon all legal questions affecting the Electrical Industry.

A regular feature in "THE ELECTRICIAN" has always been the reports of meetings of Electrical Companies and Corporations, and the completest possible record of financial items relating to the Electrical Industry. A complete Share List of Electrical Investments is given.

Finally, "THE ELECTRICIAN" has been of incalculable service to technical education, and has done much to make the general study of electricity the reality it has undoubtedly become. No aspirant to honour and renown in the electrical profession can hope to keep abreast of the never-ceasing stream of discoveries of new applications of electricity to every-day commercial pursuits who does not diligently peruse the columns of "THE ELECTRICIAN," which is pre-eminently the leading electrical journal.

"The Electrician" COMMERCIAL and INDUSTRIAL SUPPLEMENT.

Issued gratis with "The Electrician" weekly.

The "COMMERCIAL AND INDUSTRIAL SUPPLEMENT" is a comprehensive record of developments in Electrical Plant, Machinery, Apparatus, &c., and of their suitability for industrial purposes.

"THE ELECTRICIAN" ELECTRICAL TRADES' DIRECTORY & HANDBOOK.

THE BIG BLUE BOOK.

Established 1882. The cheapest, largest and only reliable Directory published for the Electrical and Kindred Trades. Published about February 20 in each year. Royal 8vo., about 2,200 pages. (SUBSCRIPTION PRICE 10s. 6d. nett, post free 11s. 3d.; British Colonies, 12s. 6d. (except Australia and South Africa, 13s. 6d.); Foreign countries, 13s. (Subscription Orders must be in the Publisher's hands by Jan. 31st.) *After date of publication*, 15s. nett, post free 15s. 9d. British Colonies, 17s. post free (except Austialia and South Africa, 18s.); Foreign countries, 17s. 6d., post free.

This Directory and Handbook is well known throughout the Electrical, Engineering and Allied Professions and Trades in all parts of the World. No expense is spared to make the work really complete and reliable. The Lists of Names and Addresses are made up from exclusive sources. The Directory portion of the book is divided into six divisions, viz., a British Division, and Colonial, Continental, Asiatic and African, Central and South American and United States Divisions. Each Division is sub-divided into an Alphabetical Section and a Classified Trades' Section. New Names and corrections to existing entries in the DIRECTORIAL portion of the book are received up to the end of January. Extra insertions are made in the Classified Trades' Section at low rates. In addition to over 950 pages of purely Directory matter, the HANDBOOK portion contains a mass (over 1,000 pages) of interesting electrotechnical statistics and commercial information relating to electricity supply, electric power distribution and transmission and electric traction in Great Britain, the Colonies and abroad, also Fire Risk Rules (British and Foreign), a full Digest of the Law of Electric Lighting, Traction, &c.

The Year's Obituary Notices, an interesting Biographical Division, the World's Patents Regulations, copious Legal Notes of the Year, and a very complete Review of the Past Year's Work (in the form of Notes) appears in each year's issue of the DIRECTORY AND HANDBOOK, which is indispensable as a work of reference concerning all matters of general electrical interest.

"THE ELECTRICIAN" SERIES
OF STANDARD BOOKS.

Aitken—AITKEN'S MANUAL OF THE TELEPHONE. By W. Aitken, M.I.E.E. Very fully Illustrated. 18s. nett. *New Edition in Preparation.*

Mr. Aitken has designed his book to cover the whole subject of Commercial Telephony. The author's close association with the practical work of telephone design, construction, erection and supervision over a long period, and the fact that he is personally identified with much of the apparatus now in use and coming into general use, entitles him to write with authority on the many problems which face the Telephone Engineer, the Telephone Manager and the Telephone Operator.

The following is a summary of the contents of Vol. I. :—

Chapter I., Elementary Theory—Chapter II., Historical Notes—Chapter III., Receivers—Chapter IV., Transmitters—Chapter V., Magneto and Primary Battery Telephone Sets—Chapter VI., Primary Batteries—Chapter VII., Private Telephone Installations—Chapter VIII., Magneto Systems, Small Switchboards—Chapter IX., Magneto Systems, Multiple Switchboards—Chapter X., The Call Wire and Ring-through Systems—Chapter XI., Central and Common Battery Circuits—Chapter XII., Apparatus used on Common-Battery Switchboards—Chapter XIII., Apparatus Racks and Distributing Frames—Chapter XIV., Standard C.B. Practice—Chapter XV., Transfer and Divided Systems—Chapter XVI., Party Line Working—Chapter XVII., Junction Line Working—Chapter XVIII, Call Wire, Operator's Instrument and other Special Circuits—Chapter XIX., Desks for Supervision and Testing—Chapter XX., The Lay-out and Wire Scheme of a Common Battery Telephone Exchange—Chapter XXI., Small Common Battery Switchboards—Chapter XXII., Common Battery Telephone Instrument Circuits, Designs and Accessories—Chapter XXIII., Extension Line and Private Line Working—Chapter XXIV., Power Plant—Chapter XXV., Telephone Trunk Line Exchanges—Chapter XXVI., Automatic Switching Systems.

Alfrec—WIRELESS TELEGRAPH DESIGNS FOR AMATEURS. By Alfrec. New Edition, with additional chapters and illustrations. 2s. 6d. nett.

In this Volume an attempt is made to convey to those whom it may interest information of a purely practical nature which has been obtained from experiments. Very few calculations and formulæ have been introduced, and those employed are very simple. The Author regards economy and cheapness, both in time and material, as the essentials of any design, and as the book is intended solely for amateurs no heed is paid to any particular wireless system. The resultant sets, both sending and receiving, may prove rather different from the usual types, but should fulfil their object.

Anderson—BOILER FEED WATER: A Practical Treatise on its Quality, Effects and Purification. By F. A. Anderson, B.Sc. (Lond.), F.I.C., F.C.S. 6s. nett.

The great increase in the working pressure of steam boilers during the last few years, and the wide adoption of water-tube boilers, have directed attention more generally to the subject of the quality of the water used for boiler feed. . . . In this book an attempt has been made to give a concise account of the most important impurities to be met with in feed waters, especially in land installations, together with the methods for their detection and removal.

Atkins—COMMON BATTERY TELEPHONY SIMPLIFIED. By W. Atkins, Telephone Engineer. 3s. nett, post free, 3s. 6d. Crown 8vo. 165 Diagrams.

Extract from Preface.—This book is essentially one for the practical man and the modern student. It does not deal with the history of the science of telephony, nor with magneto systems which are now obsolete, excepting to explain the working of small magneto instruments which are frequently met with in private installations, where the distance from the public exchange is too great for common battery working. Although minute details of the apparatus employed are not given, it is hoped that the essential principles underlying the action of all such apparatus is sufficiently well described. All diagrams of circuit arrangements have been drawn as simple as possible. Actual wiring diagrams are, therefore, not given, but it is believed that these latter will present a less formidable appearance than they do to many at present if the simple sketches in this book are looked into.

Atkins—THE PRINCIPLES OF AUTOMATIC TELEPHONY. By W. Atkins, Telephone Engineer. *New Edition end* 1915. 2s. 6d. nett, post free 2s. 9d.

This book seeks to put the general principle of Automatic Telephony in a simple form, so that the student and engineer may understand how the apparatus works and what it has to do.

Ayrton—THE ELECTRIC ARC. By Mrs. Ayrton, M.I.E.E. Very fully Illustrated. Price 12s. 6d.

Baines—BEGINNER'S MANUAL OF SUBMARINE CABLE TESTING AND WORKING. By G. M. Baines. Cloth. 7s. 6d. nett, post free 8s.

This book has been written to meet the requirements of those about to commence the study of Submarine Telegraphy. All subjects demanding attention have been brought within the scope of the volume and have been dealt with at sufficient length to enable an intelligible idea to be obtained of them. With regard to the algebraical portion of the study, all the formulæ have been worked out step by step, and, where convenient, have been supplemented by arithmetical equivalents. The book is divided into 18 chapters, and deals with: Batteries, Ohm's Law, Joint Resistance, Wheatstone Bridge, Bridge Measurements, Insulation Test by Direct Deflection, Inductive Capacity, Internal Resistance and E.M.F. of a Battery, &c., Current Strength in Wheatstone Bridge, Tests of Broken or Faulty Cables, and Description of Submarine Telegraph Apparatus, &c.

Barker, E. Raymond—*See* RAYMOND-BARKER, E., p. 12

Beaumont—THE STEAM-ENGINE INDICATOR AND INDICATOR DIAGRAMS. Edited by W. W. Beaumont, M.I.C.E., M.I.M.E., &c. 5s. nett, post free.

Bond—RATING OF ELECTRIC LIGHTING, ELECTRIC TRAMWAY AND SIMILAR UNDERTAKINGS. By W. G. Bond. Cloth, 8vo price 2s. 6d. nett.

This little book is intended for the use of Directors, Secretaries, Engineers and other Officials connected with Electric Traction, Lighting and Power Distribution Companies.

Boult—COMPREHENSIVE INTERNATIONAL WIRE TABLES FOR ELECTRIC CONDUCTORS. By W. S. Boult. Price 4s. post free.

Broughton—ELECTRIC CRANES: Their Design, Construction and Application. By H. H. Broughton, A.M.I.E.E., A.Am.I.E.E., A.M.I.M.E., Whitworth Exhibitioner, Head of the Electrical Engineering Department and Lecturer on Machine Design and Structures at the Municipal Technical College, Brighton.

25s. *nett. Postage* 9d. *U.K., Abroad* 1s. 8d. *About* 900 *pages. More than* 600 *Illustrations (nearly all original for this book). Nearly* 100 *Tables (many of special value), Folding Plates, Scale Drawings, Curves and specially made Photographic reproductions.*

This book is the most comprehensive work ever published on the important subject of the Design, Construction and Application of Electric Cranes and Hoists. It is the first Volume of a complete Manual on Lifting and Hauling Machinery. Careful attention is given to the question of the electric equipment of cranes, and the treatment is such as to be readily understood by those engineers, designers and draughtsmen whose knowledge of heapy electrical engineering is limited to elementary principles. In the chapter devoted to electrical equipment, motors, electro-mechanical brakes, controllers, collectors switchgear and wiring are considered. A large number of wiring diagrams are included, and safety devices of approved construction are described. The important question of the rating of motors for intermittent service is considered at length, and keeping in mind the needs of mechanical engineers, practical information takes the place of theoretical discussion. Many fully worked out examples are given in connection with the section on structural steelwork, and constants of the utmost value to the consultant and to the designer are included. Dimensioned working drawings of cross-girders, gantries, jibs, pedestals and superstructures characterise the section on the structural part of cranes, as also do the typical specifications of work of the highest class. The question of the power required to drive cranes and crane mechanisms is considered in detail, and several examples are worked out. Special attention is given to mechanical equipment, and a large number of constants and design coefficients are included. The design, construction and arrangement of mechanical brakes also receive adequate treatment. Considerable space is devoted to overhead cranes, to gantry cranes and to jib cranes, and the examples selected represent the most recent practice The many special cranes and crane systems used in shipyards and in steelworks are described in detail, and the drawings of the British, German and American built cranes will be invaluable to designers, constructors and users.

There are 15 Chapters, and the following is a synopsis of the Contents: Chapter I., Introductory—Chapter II., Electric Equipment—Chapter III.. Structural Steelwork—Chapter IV., Power required to Drive Cranes—Chapter V., Mechanical Equipment—Chapter VI., Crane Arrangements—Chapter VII., Arrangement of Crane Mechanisms—Chapter VIII., Design of Crane Mechanisms—Chapter IX., Overhead Travelling Cranes and Gantry Cranes—Chapter X., Jib Cranes—Chapter XI., Building Siip Equipments—Chapter XII., Fitting-out Basin Cranes—Chapter XIII., Steelworks Cranes—Chapter XIV., Specifications—Chapter XV., Properties of Sections and Conductors.

Carter—MOTIVE POWER AND GEARING FOR ELECTRICAL MACHINERY: A Treatise on the Theory and Practice of the Mechanical Equipment of Power Stations for Electric Supply, and for Electric Traction. By the late E. Tremlett Carter, C.E., M.I.E.E. 650 pages, 200 Illustrations, and over 80 Tables of Engineering Data. Revised by G. THOMAS-DAVIES. Price 5s. nett.

Part I.—Introductory. Part II.—The Steam Engine. Part III.—Gas and Oil Engines.
Part IV.—Water Power Plant. Part V.—Gearing. Part VI.—Types of Power Stations.

Cooper—PRIMARY BATTERIES: THEIR CONSTRUCTION AND USE. By W. R. Cooper, M.A. Price 12s. 6d. nett. *New Edition nearly ready.*

Author's Preface—Extract.—Primary Batteries form a subject from which much has been hoped, and but little realised. But even so, it cannot be said that the advance has been small; and consequently no apology is offered for the present volume, in which the somewhat scattered literature of the subject has been brought together. Recent years have seen important additions to the theory of the voltaic cell, and therefore a considerable number of pages have been devoted to this part of the subject, although it is impossible to do more than give a superficial sketch of the theory in a volume like the present. With regard to the practical part of the subject, this volume is not intended to be encyclopædic in character; the object has been rather to describe those batteries which are in general use, or of particular theoretical interest. As far as possible, the Author has drawn on his personal experience, in giving practical results, which, it is hoped, will add to the usefulness of the book. Owing to the importance of the subject, Standard Cells have been dealt with at some length. Those cells, however, which are no longer in general use are not described; but recent work is summarised in some detail so as to give a fair idea of our knowledge up to the present time. A chapter is also devoted to Carbon-Consuming Cells.

Cooper—*See* "THE ELECTRICIAN" PRIMERS, page 8.

Dawson—ELECTRIC TRACTION ON RAILWAYS. By Philip Dawson, M.Inst.C.E., M.I.E.E., author of "Electric Tramways and Railways," and "The Engineering and Electric Traction Pocket Book." 1,000 pages, over 600 illustrations (nearly all original); royal 8vo. Price 25s. nett, postage 6d. U.K., 1s. 4d. abroad.

This book deals entirely with the application of electric traction to railways, as distinguished from tramways. All the calculations necessary to determine the size and type of motor required under any given circumstances are carefully gone into, and are such as are used in actual practice. The important question of the calculation of motor-driven axles is also considered in detail, and a complete example worked out. The impedance of single-phase lines equipped with overhead conductors is carefully gone into, and actual examples given to show how any quantity can be ascertained beforehand for any given system. The question of the calculation and construction of catenary suspension for single-phase railways is fully worked out, and examples of different forms of construction given. An easy, simple and elementary theory of the single-phase motor has been specially prepared for this book, so as to explain, as clearly and simply as possible, the principles involved in its construction and operation. Special attention is given to practical examples in connection with the construction of trucks and car bodies. Multiple unit control, both for continuous and alternating currents, is fully gone into, and diagrams for all the most important constructions are given, as well as illustrations of special details. Careful attention is given to theoretical and practical considerations in connection with the design and construction of third rail, and all the most important methods hitherto adopted are amply described and fully illustrated. A chapter is devoted to electric locomotives, both continuous and alternating current, designed for all classes of service. A limited amount of space is devoted to the most important features connected with the design and construction of power stations and sub-stations and general details. To the subject of accumulator traction for railways all necessary space has been accorded. Considerable attention is given to financial details and estimates as regards working costs, maintenance costs, and all the numerous financial details required for the successful operation of the electrified line. The work has been prepared on the basis that the reader is acquainted with the principles underlying electrical engineering data as well as with the principles of railway construction and apparatus, and the book is intended to supply that special knowledge, both practical and theoretical, which is essential to every engineer who has either to equip or operate electric railways.

Dick and Fernie—ELECTRIC MAINS AND DISTRIBUTING SYSTEMS. By J. R. Dick, B.Sc., M.I.E.E., and F. Fernie, A.M.I.C.E., A M.I.E.E. *New Edition in preparation.*

The authors have dealt with the subject in such a way that engineers and designers of underground cable systems will have available, in a convenient form for reference, sufficient information. It is also hoped that the book will prove helpful to students, as well as to engineers and contractors, whose requirements, especially from the point of view of design, have been primarily considered.

Down—"THE ELECTRICIAN" HANDY COPPER WIRE TABLES AND FORMULÆ FOR EVERYDAY USE IN FACTORIES AND WORKSHOPS. By P. B. Down, Wh.Ex., A.M.I.M.E. Price 2s. 6d. nett.

Drysdale and Jolley—ELECTRICAL MEASURING INSTRUMENTS: THEIR DESIGN, CONSTRUCTION AND APPLICATION. By Dr. C. V. Drysdale and A. C. Jolley. *In preparation.*

Eccles—WIRELESS TELEGRAPHY AND TELEPHONY: HANDBOOK OF FORMULÆ, DATA AND INFORMATION. By W. H. Eccles, D.Sc. *Now Ready.* 12s. 6d. nett, post free 13s.

The book will be a classified collection of information, data and tables necessary or likely to be useful to designers and investigators in Radiotelegraphy. The intention of the Author has been to set out, not merely a bare statement of observed and recorded facts in easily accessible form, but also to give brief accounts of the position of modern thought and speculation, without allowing the work to become an expository treatise. Whenever it has been found impossible to convey full information intelligibly without some allusion to principles, the necessary explanatory matter has been introduced, but it has been made especially brief when full discussions are available in well-known treatises. Many of the formulæ given in the book have been re-worked and corrected, many are now published for the first time. There are a number of abacs for facilitating the rapid application of formulæ frequently needed in approximate calculations.

Eck—LIGHT, RADIATION AND ILLUMINATION. From German of Paul Högner. Translated by Justus Eck, M.A., M.I.E.E. Price 6s. nett.

The important subject of Light, Radiation and Illumination is dealt with by Mr. Högner in a very complete way, and the student, as well as the engineer and manufacturer, will find Mr. Eck's translation of Mr. Högner's excellent scientific and literary work of the greatest value in connection with this subject.

"THE ELECTRICIAN" WIREMAN'S POCKET BOOK AND ELECTRICAL CONTRACTOR'S HANDBOOK—*See* ROBINSON (A. W.) and WARRILOW (W. E.), p. 12.

Ewing—MAGNETIC INDUCTION IN IRON AND OTHER METALS. By Sir J. A. Ewing, F.R.S. 382 pages, 173 Illustrations. Third Edition, Second Issue. Price 10s. 6d. nett.

Synopsis of Contents.—After an introductory chapter, which attempts to explain the fundamental ideas and the terminology, an account is given of the methods which are usually employed to measure the magnetic quality of metals. Examples are then quoted, showing the results of such measurements for various specimens of iron, steel, nickel and cobalt. A chapter on Magnetic Hysteresis follows, and then the distinctive features of induction by very weak and by very strong magnetic forces are separately described, with further description of experimental methods, and with additional numerical results. The influences of Temperature and of Stress are discussed. The conception of the Magnetic Circuit is then explained, and some account is given of experiments which are best elucidated by making use of this essentially modern method of treatment.

Fisher and Darby—STUDENTS' GUIDE TO SUBMARINE CABLE TESTING.

By H. K. C. Fisher and J. C. H. Darby. New and Enlarged Edition, April, 1913. Fully Illustrated. Price 7s. 6d. nett, post free; abroad, 8s.

The authors of this book have, for some years past, been engaged in the practical work of Submarine Cable Testing in the Eastern Extension Telegraph Company's service, and have embodied their experience in a Guide for the use of those in the Telegraph Service who desire to qualify themselves for the examinations which the Cable Companies have recently instituted. To those desirous of entering the Cable Service Messrs. Fisher and Darby's book is indispensable, as it is now necessary for probationers to pass these examinations as part of the qualification for service.

A valuable set of Questions and Answers is added to the New and Enlarged Edition.

Fleming—ELECTRICAL LABORATORY NOTES AND FORMS.

Arranged and prepared by Prof. J. A. Fleming, D.Sc., F.R.S., &c. *Revised as required.*

This important Series of Notes and Forms for the use of Students in University and other Electro-technical Classes has a world-wide reputation, and many thousands of copies have been sold. From time to time, as considered desirable, the Notes and Forms have been corrected or re-written, but the original divisions of the forty Forms into "Elementary" and "Advanced" has hitherto been observed. At the same time it is realised that the time has come for additions to be made to the original Set, and Dr. Fleming has written Ten Additional Notes and Forms (Nos. 41 to 50). It should be remembered that the numerical order observed in the above list has no relation to the difficulty or class sequence of the exercise, but is simply a reference number for convenience. The Subjects of the additional Notes and Forms are:—

No.	Subject.
1.	The Exploration of Magnetic Fields.
2.	The Magnetic Field of a Circular Current.
3.	The Standardization of a Tangent Galvanometer by the Water Voltameter.
4.	The Measurement of Electrical Resistance by the Divided Wire Bridge.
5.	Calibration of the Ballistic Galvanometer.
6.	The Determination of Magnetic Field Strength.
7.	Experiments with Standard Magnetic Fields
8.	The Determination of the Magnetic Field in the Air Gap of an Electromagnet.
9.	The Determination of Resistance with the Post Office Pattern Wheatstone Bridge.
10.	The Determination of Potential Difference by the Potentiometer.
11.	The Measurement of a Current by the Potentiometer.
12.	A Complete Report on a Primary Battery.
13.	The Standardization of a Voltmeter by the Potentiometer.
14.	A Photometric Examination of an Incandescent Lamp.
15.	The Determination of the Absorptive Powers of Semi-Transparent Screens.
16.	The Determination of the Reflective Power of Various Surfaces.
17.	The Determination of the Electrical Efficiency of an Electromotor by the Cradle Method.
18.	The Determination of the Efficiency of an Electromotor by the Brake Method.
19.	The Efficiency Test of a Combined Motor-Generator Plant.
20.	Test of a Gas Engine and Dynamo Plant.
21.	The Determination of the Electrical Resistivity of a Sample of Metallic Wire.
22.	The Measurement of Low Resistances by the Potentiometer.
23.	The Measurement of Armature Resistances.
24.	The Standardization of an Ammeter by Copper Deposit.
25.	The Standardization of a Voltmeter by the Potentiometer.
26.	The Standardization of an Ammeter by the Potentiometer.
27.	The Determination of the Magnetic Permeability of a Sample of Iron.
28.	The Standardization of a High Tension Voltmeter.
29.	The Examination of an Alternate Current Ammeter.
30.	The Delineation of Alternating Current Curves.
31.	The Efficiency Test of a Transformer.
32.	The Efficiency Test of an Alternator.
33.	The Photometric Examination of an Arc Lamp.
34.	The Measurement of Insulation and High Resistance.
35.	The Complete Efficiency Test of a Secondary Battery.
36.	The Calibration of Electric Meters.
37.	Delineation of Hysteresis Curves of Iron.
38.	The Examination of a Sample of Iron for Magnetic Hysteresis Loss.
39.	The Determination of the Capacity of a Concentric Cable.
40.	The Hopkinson Test of a Pair of Dynamos.
41.	Determination of Dynamo Efficiency by Routin's Method.
42.	Separation of Hysteresis and Eddy Current Losses in Continuous-Current Dynamo Armatures.
43.	Efficiency Test of Two Equal Transformers by the Differential (Sumpner's) Method.
44.	Measurement of the Efficiency and Power Factor of a Polyphase Induction Motor by the Wattmeter Method.
45.	Determination of the Characteristic Curves of Dynamo Machines.
46.	The Absolute Measurement of Capacity.
47.	The Measurement of Inductances.
48.	The Test of a Rotary Converter.
49.	The Parallelisation of Alternators.
50.	The Examination of an Alternating-Current Motor.

These "Electrical Laboratory Notes and Forms" have been prepared to assist Teachers, Demonstrators and Students in Electrical Laboratories, and to enable the Teacher to economise time. They now consist of a series of 50 Exercises in Practical Electrical Measurements and Testing. For each of these Exercises a four-page Report Sheet has been prepared, two and sometimes more pages of which are occupied with a condensed account of the theory and practical instructions for performing the particular Experiment, the other pages being ruled up in lettered columns, to be filled in by the Student with the observed and calculated quantities. These Exercises are perfectly general, and can be put into practice in any Laboratory.

Each Form is supplied either singly at 4d. nett, or at 3s. 6d. per dozen nett (assorted or otherwise as required); in Sets of any Three at 1s. nett; or the Complete Set of 50 Exercises, price 12s. 6d. nett, or in a handy Portfolio, 14s. nett, or bound in strong Cloth Case, price 15s. nett. Spare Tabulated Sheets for Observations, price 1d. each nett. Strong Portfolios can also be supplied, price 1s. 6d. each. The best quality Foolscap Sectional Paper for Drawings (16in. by 13in.) can be supplied, price 9d. per dozen sheets nett.

A Sample Copy of any one of the Notes and Forms will be sent post free to any Teaching Establishment, or to the Professor or Demonstrator of a Class for Electro-Technology. A complete Prospectus will also be sent post free on application.

Fleming—THE ALTERNATE CURRENT TRANSFORMER IN THEORY AND PRACTICE.

By Prof. J. A. Fleming, M.A., D.Sc., F.R.S., Vol. I. The Induction of Electric Currents. Second Edition Over 600 pages and 213 illustrations, 12s. 6d. post free; abroad, 13s. Vol. II. The Utilisation of Induced Currents. Third issue. Over 600 pages and 300 illustrations, 12s. 6d. post free; abroad, 13s.

Since the first edition of this Treatise was published, the study of the properties and applications of alternating electric currents has made enormous progress. . . . . The Author has, accordingly, rewritten the greater part of the chapters, and availed himself of various criticisms, with the desire of removing mistakes and remedying defects of treatment. In the hope that this will be found to render the book still useful to the increasing numbers of those who are practically engaged in alternating-current work, he has sought, as far as possible, to avoid academic methods and keep in touch with the necessities of the student who has to deal with the subject not as a basis for mathematical gymnastics but with the object of acquiring practically useful knowledge.

Fleming—A HANDBOOK FOR THE ELECTRICAL LABORATORY AND TESTING ROOM.

By Dr. J. A. Fleming, M.A., F.R.S., M.R.I., &c. Vol. I., price 12s. 6d. nett, post free 13s. Vol. II., 14s. nett.

This Handbook has been written especially to meet the requirements of Electrical Engineers in Supply Stations, Electrical Factories and Testing Rooms. The Book consists of a series of Chapters each describing the most approved and practical methods of conducting some one class of Electrical Measurements, such as those of Resistance, Electromotive Force, Current, Power, &c., &c. It does not contain merely an indiscriminate collection of Physical Laboratory processes without regard to suitability for Engineering Work. The Volumes contain a useful Chapter on the Equipment of Electrical Laboratories and numerous Tables of Electrical Data.

SYNOPSIS OF CONTENTS.

Vol. I.

Chapter I.—Equipment of an Electrical Testing Room.
,, II.—The Measurement of Electrical Resistance.
,, III.—The Measurement of Electric Current.
,, IV.—The Measurement of E.M.F.
,, V.—The Measurement of Electric Power.

Vol. II.

Chapter I.—The Measurement of Electric Quantity and Energy.
,, II.—The Measurement of Capacity and Inductance.
,, III.—Photometry.
,, IV.—Magnetic and Iron Testing.
,, V.—Dynamo, Motor and Transformer Testing.

Fleming—HERTZIAN WAVE WIRELESS TELEGRAPHY:

A Reprint of articles in the "Popular Science Monthly," based upon Dr. Fleming's Cantor Lectures before the Society of Arts, 1903. By Dr. J. A. Fleming, F.R.S. 3s. 6d. nett.

Fleming—ELECTRIC LAMPS AND ELECTRIC LIGHTING.

By Prof. J. A. Fleming, M.A., D.Sc., F.R.S. Second Edition. Price 4s. nett.

Fleming—THE CENTENARY OF THE ELECTRIC CURRENT.

1799—1899. By Prof. J. A. Fleming, F.R.S. 2s. nett.

Fleming—THE ELECTRONIC THEORY OF ELECTRICITY.

By Prof. J. A. Fleming, M.A., D.Sc., F.R.S. Price 1s. 6d. post free.

Fynn—THE CLASSIFICATION OF ALTERNATE CURRENT MOTORS.

By V. A. Fynn, M.I.E.E. Fully Illustrated. 3s. nett.

Garrard—ELECTRIC SWITCH AND CONTROLLING GEAR.

A Handbook on the Design, Manufacture and Use of Switchgear and Switchboards in Central Stations, Factories and Mines. By C. C. Garrard, Ph.D., M.I.E.E. *Now Ready.* 15s. nett. post free 15s. 9d.

CONTENTS:—

Chapter I., Materials and Manufacturing Methods; Chapter II., Apparatus and Making and Breaking Electric Circuits; Chapter III., Apparatus for Preventing a Dangerous Condition of the Current Flowing; Chapter IV., Apparatus for Regulating the Amount of Current; Chapter V., Apparatus for Starting and Controlling Electrical Running Machinery; Chapter VI., Low and Medium Tension Switchboards; Chapter VII., High-tension and Extra-high-tension Switchboards; Chapter VIII., Apparatus for Protecting Electrical Machinery against Abnormal Electrical Conditions; Appendices giving abstracts of the National Electrical Code, American Standardisation Rules, I.E.E. Wiring Rules, Board of Trade Regulations, &c.

"THE ELECTRICIAN" PRIMERS.

By Various Authors. [COPYRIGHT.]

EDITED BY

Mr. W. R. COOPER, M.A., B.Sc., M.I.E.E., A.M.I.C.E., F.Ph.S., &c.

Each Primer is complete in itself and gives a clear insight into the subject dealt with.

There are, in all, **84** PRIMERS and Glossary in this Collection. The complete set comprises **1,100 pages** and nearly **600 illustrations,** the greater portion specially drawn and made for these volumes, and consequently Copyright. Following is a list of the subjects dealt with :—

Vol. I. THEORY *(25 Primers.) Price 3s. 6d. nett. (For price of Single Copies see below.)*

1. Effects of an Electric Current (—)
2. Conductors and Insulators .. (—)
3. Ohm's Law .. .. .. (8)
4. Electrical Units .. .. (—)
5. Curves and their Uses .. (4)
6. Primary Batteries .. .. (7)
7. Arrangement of Batteries .. (8)
8. Electrolysis .. .. .. (1)
9. Secondary Batteries .. .. (10)
10. Alternating Currents .. (4)
11. Lines of Force .. .. .. (9)
12. Magnetism and the Magnetic Properties of Iron .. .. (4)
13. Galvanometers .. .. .. (11)
14. Electrical Measuring Instruments .. .. (17)
15. Electrical Measurements .. (14)
16. Electricity Meters (Direct Current) .. .. (15)
16A. Ditto (Alternating Current) (19)
17. The Induction Coil .. .. (2)
18. Condensers .. .. .. (2)
19. Influence Machines .. .. (4)
20. Rontgen Rays & Radiography (8)
21. Lightning Protectors .. .. (6)
22. Thermopiles .. .. .. (4)
23. Arithmetic of Electricity .. (—)
24. Constants and Tables .. .. (3)

In addition to over *Eighty Primers* comprised in the three volumes, all upon carefully selected subjects of both scientific and industrial interest, each volume contains an ample **Glossary of Electro-Technical Words, Terms & Phrases,** to aid the Student, Artisan and General Reader in his comprehension of the subjects dealt with. The individual Primer is followed by a List of Suitable Books, &c., to be consulted where the study of any particular subject is desired to be extended.

Vol. II. *Price 6s. nett. (For Price of Single Copies see below.)*

ELECTRIC TRACTION, ELECTRIC LIGHTING and ELECTRIC POWER

(32 Primers.)

25. Dynamos and Direct Current Motors (8)
26. Alternators and Alternate-Current Motors .. .. (12)
27. Transformers and Converters.. .. (12)
28. Testing Electrical Machinery .. .. (2)
†29. Management of Dynamos and Electric Machinery .. .. (2)
30. Electric Wires and Cables .. .. (5)
31. Underground Mains .. .. .. (7)
32. Switchboards .. .. (12)
33. Switchboard Devices .. .. .. (22)
34. Systems of Elec. Distribution .. .. (5)
35. Electric Transmission of Power .. (—)
36. Tramway Traction by TROLLEY .. (17)
37. Tramway Traction by CONDUIT .. (5)
38. Tramway Traction by SURFACE CONTACT .. .. (8)
39. Tramway Traction by ACCUMULATORS .. .. (2)
40. Electric Railways—Surburban Lines (6)
41. Electric Automobiles .. .. .. (6)
42. Electric Ignition .. .. (17)
43. Incandescent Lamps .. .. .. (12)
44. Arc Lamps .. .. (9)
45. Street Lighting .. .. (3)
†46. House Wiring for Electric Light .. (7)
47. Electric Driving in Factories and Electric Cranes.. .. .. .. (1)
48. Electric Lifts.. .. .. (3)
†49. Steam Engines .. .. (—)
50. Steam Boilers .. .. (10)
51. The Equipment of Electricity Generating Stations .. .. (4)
†52. Gas Engines .. .. (14)
*52A Oil Engines .. .. (9)
53. Producer Plant .. .. (11)
54. Comparative Advantages of Steam and Producer Gas for Power Production .. .. (—)
55. Designing and Estimating for Small Installations .. .. (—)

Vol. III. *Price 4s. 6d. nett. (For price of single Copies see below.)*

TELEGRAPHY, TELEPHONY, ELECTROLYSIS and MISCELLANEOUS APPLICATIONS OF ELECTRICITY.

(27 Primers.)

Telegraphy :—

56. Elements of Land, Submarine and Wireless .. ..
57. Duplex .. ..
58. Double-Current Working .. ..
†59. Diplex and Quadruplex .. ..
60. Multiplex .. ..
*60A. Central Battery Telegraphs ..
†61. Automatic Telegraph Apparatus (Wheatstone Transmitter, Auto. Curb Transmission, Auto. Transmission for Submarine Cables) ..
62. Cable Stations: General Working and Electrical Adjustments .. ..
†63. Laying, Jointing and Repair of Submarine Cables .. ..
64. Testing Submarine Cables .. ..
65. Testing Land Lines .. .. ..
66. Aerial Telegraph Line Construction and Jointing .. ..
67. Wireless Telegraphy .. .. ..

Telephony :—

68. The Telephone .. ..
69. Telephone Sets .. ..
70. Telephone Exchanges .. .. ..
71. Telephone Lines .. ..
72. Electric Bell Fitting and Internal Telephone Wiring .. .. ..

Miscellaneous :—

73. Electric Heating & Cooking ..
74. Electric Welding .. .. ..
75. Electric Furnaces .. .. ..
76. Electro-Deposition .. .. ..
77. Industrial Electrolysis .. .. ..
78. Photo Engraving .. ..
†79. Electric Clocks .. ..
*79A. Electric Impulse Dials .. ..
80. Block Signalling on Railways ..

* Added 1914. (New Primers are added from time to time.) † Revised 1914-15. (The Primers are under constant revision.)

(The figures in parentheses indicate the number of Illustrations.)

Price **3d.** each, post free. Six copies of **any one Primer** post free for **1s. 2d.,** 12 copies **2s.,** 25 copies **4s.** 50 copies **7s. 6d.,** 100 copies **14s.** Or 50 copies of the **Primers assorted** (not less than 6 of any one Primer) for **9s.**; or 100 copies of the Primers assorted (not less than 12 of any Primer) for **16s. 6d.** *Larger numbers by arrangement.*

Additional Primers are in preparation and are included in the Volumes as they are published.

"THE ELECTRICIAN" PRIMERS are Published

In ONE VOLUME, cloth, price **10s. 6d.** nett (By post, **11s.**)

In THREE VOLUMES, price **12s. 6d.** nett, complete **Postage 9d. extra.**

or

Vol. I. price **3s. 6d.** net
Vol. II. ditto **6s. 0d.** net
Vol. III. ditto **4s. 6d.** net
(If sent by post, **3d.** extra per volume.

And in separate form as above detailed.

Geipel and Kilgour—A POCKET-BOOK OF ELECTRICAL ENGINEERING FORMULÆ, &c. By W. Geipel and H. Kilgour. 7s. 6d. nett.

Gerhardi—ELECTRICITY METERS, THEIR CONSTRUCTION AND MANAGEMENT. A Practical Manual for Central Station Engineers, Distributing Engineers, and Students. By C. H. W. Gerhardi. 8vo. Fully illustrated. 9s. nett.

The Author of this valuable Practical Manual on the Management of Electricity Meters has had many years' experience with Electricity Meters as chief of the Testing Department of the largest electricity supply undertaking in the United Kingdom. Mr. Gerhardi's intimate acquaintance with the working of all existing meters on the market, and with the details of their construction, is a guarantee that the book will meet the requirements of those engaged in work in which the Electricity Meter forms an essential part.

Goldschmidt—ALTERNATING CURRENT COMMUTATOR MOTORS. By Dr. Ing. R. Goldschmidt. Over 600 pages. Fully Illustrated. 6s. 6d. nett.

This work is divided into two parts. The first consists of a series of articles on Commutator Motors which have been reprinted from *The Electrician* and revised and expanded by the author. The second part is also made up of articles which gives the result of the author's experience on the Leakage of Induction Motors. There are many Tables and Curves intended for the use of the designer of Induction Motors.

Gore—THE ART OF ELECTROLYTIC SEPARATION OF METALS. By Dr. George Gore. Over 300 pages, 106 illustrations. Price 10s. 6d. post free.

Dr. Gore's work is of the utmost service in connection with all classes of electrolytic work connected with the refining of metals. The book contains both the science and the art of the subject (both the theoretical principles upon which the art is based and the practical rules and details of technical application on a commercial scale), so that it is suitable for both students and manufacturers.

Gore—ELECTRO-CHEMISTRY. By Dr. G. Gore. Price 2s.

At the time when this book first appeared no separate treatise on Electro-Chemistry existed in the English language, and Dr. Gore has collected together a mass of useful information, arranged in consecutive order, and giving brief descriptions of the laws and general principles which underlie Electro-Chemistry.

Hall—ELEMENTARY THEORY OF ALTERNATE CURRENT WORKING. By Capt. G. L. Hall, R.E. Fully Illustrated. Price 3s. 6d. net.

CONTENTS:—

Chap. I., Alternating Currents; Chap. II., Inductance; Chap. III., Capacity; Chap. IV., Resonance; Chap. V., Power Measurement; Chap. VI., Polyphase Systems; VII.. Transformers; Chap. VIII., Generators; Chap. IX., Synchronous Motors; Chap. X., Induction Motors; Chap. XI., Commutator Motors.

Hansard—TRAMWAY TRACTIVE EFFORT AND POWER DIAGRAM. By A.G. Hansard. 2s.6d., post free in tube 3s., mounted on linen, 5s., post free.

Heather—ELECTRICAL ENGINEERING FOR MECHANICAL AND MINING ENGINEERS. By H. J. S. Heather, B.A., M.I.C.E., M.I.E.E. 356 pages, 183 illustrations. *Now Ready.* 9s. nett, post free 9/6.

The basis of the present work is a series of 20 Lectures prepared for and delivered to the resident mechanical engineers of the mines of the Witwatersrand, South Africa. The matter of the Lectures has been carefully revised and amplified by the author, so that the book should prove very useful, not only to Resident Engineers and Managers of Mines, but to Mechanical Engineers generally and all who are engaged in the Care and Management of Electrical and Mining Plant and Machinery.

Synopsis of Lectures.—I., The Electric Circuit, Continuous Currents; II., Resistance; III. and IV., Alternating Currents; V., Recapitulation of First Four Lectures; VI., Electrical Measurements; VII. and VIII., Continuous-current Dynamos; IX., Continuous-current Motors and Parallel Running of Dynamos; X. and XI., Alternating-current Generators; XII., Synchronous Motors and Parallel Running of Alternators; XIII. and XIV., Transformers; XV. and XVI., Polyphase Systems; XVII., Polyphase Transformations; XVIII. and XIX., Induction Motors; XX., The Effects of Running Under Abnormal Conditions.

Heaviside—ELECTROMAGNETIC THEORY. By Oliver Heaviside. **Vol. I.** Second issue. Price 12s.6d., post free 13s. **Vol. II.** Price 12s. 6d. post free abroad 13s. **Vol. III.** Price 21s. nett, post free 21s. 6d.; abroad 22s.

Extract from Preface to Vol. I.—This work is something approaching a connected treatise on electrical theory, though without the strict formality usually associated with a treatise. The following are some of the leading points in this volume. The first chapter is introductory. The second consists of an outline scheme of the fundamentals of electromagnetic theory from the Faraday-Maxwell point of view, with some small modifications and extensions upon Maxwell's equations. The third chapter is devoted to vector algebra and analysis, in the form used by me in former papers. The fourth chapter is devoted to the theory of plane electro magnetic waves, and, being mainly descriptive, may perhaps be read with profit by many who are unable to tackle the mathematical theory comprehensively. I have included the application of the theory (in duplex form) to straight wires, and also an account of the effects of self-induction and leakage.

Extract from Preface to Vol. II.—From one point of view this volume consists essentially of a detailed development of the mathematical theory of the propagation of plane electromagnetic waves in conducting dielectrics, according to Maxwell's theory, somewhat extended. From another point of view, it is the development of the theory of the propagation of waves along wires. But on account of the important applications, ranging from Atlantic telegraphy, through ordinary telegraphy and telephony, to Hertzian waves along wires, the Author has usually preferred to express results in terms of the concrete voltage and current, rather than the specific electric and magnetic forces belonging to a single tube of flux of energy. . . . The theory of the latest kind of so-called wireless telegraphy (Lodge, Marconi, &c.) has been somewhat anticipated, since the waves sent up the vertical wire are hemispherical, with their equatorial bases on the ground or sea, which they run along in expanding. (*See* § 60, Vol. I.; *also* § 393 in this volume.) The author's old predictions relating to skin conduction, and to the possibilities of long-distance telephony have been abundantly verified in advancing practice; and his old predictions relating to the behaviour of approximately distortionless circuits have also received fair support in the quantitative observation of Hertzian waves along wires.

Vol. III. of Mr. Oliver Heaviside's very important work on Electromagnetic Theory is **Now Ready** and it will be found to be a most important addition to the previous volumes. The opening chapter of Vol. III. deals with "Waves from Moving Sources" and after two appendices on the Size and Inertia of Electrons and on Vector Analysis, there is a lengthy and very valuable chapter on "Waves in the Ether." The new volume will provide the means of solving many of the problems which those engaged in practical electrical industrial operations are called upon to consider, and it will also be a work of inestimable value to the scientist.

Heaviside—"ELECTRICAL PAPERS." In Two Volumes. By Oliver Heaviside. Price (*when obtainable*) £3 : 3s. nett. *Scarce.* Occasionally copies can be supplied.

The first twelve articles of Vol. I. deal mainly with Telegraphy, and the next eight with the Theory of the Propagation of Variations of Current along Wires. Then follows a series of Papers relating to Electrical Theory in general.

The contents of Vol. II. include numerous Papers on Electro-Magnetic Induction and its Propagation, on the Self-Induction of Wires, on Resistance and Conductance Operators and their Derivatives Inductance and Permittance, on Electro-Magnetic Waves, a general solution of Maxwell's Electro-Magnetic Equations in a Homogeneous Isotropic Medium, Notes on Nomenclature, on the Theory of the Telephone, on Hysteresis, Lightning Conductors, &c.

Hickman—THE PRACTICAL WIRELESS SLIDE RULE. By Dr. H. R. Belcher Hickman. 2s. 6d. nett, in envelope, post free, 2s. 9d. In leather case 3s., post free 3s. 3d.

Dr. Belcher Hickman's Practical Wireless Slide Rule will prove an indispensable companion to all who have calculations to make in connection with Wireless Telegraphy, Telephony and allied subjects. The Slide Rule has been very carefully prepared, and has been approved by several of our leading wireless experts. The fullest directions are provided for using the rule.

Houstoun—STUDIES IN LIGHT PRODUCTION. By R. A. Houstoun, M.A., Ph.D., D.Sc. 5s. nett, post free 5s. 6d. 8vo. Fully illustrated

These studies were written with the purpose of collecting information about the efficiency of our artificial illuminants as energy transformers, both for the sake of rendering the facts readily accessible and also for information as to the lines future progress is likely to take. From this standpoint photometry is not important, and consequently it has not been considered.

The work is composed of twelve chapters, as follows:—Chapter I., The Energy Spectrum; II., The Black Body; III., Flames; IV., The Welsbach Mantle; V., The Carbon Glow Lamp: VI., The Arc: VII., The Nernst Lamp; VIII., Metal Filament Lamps; IX., The Mercury Arc; X., The Light of the Future; XI., On the Absolute Measurement of Light: A Proposal for an Ultimate Light Standard; XII., On Apparatus and Experimental Methods.

Jehl—CARBON MAKING FOR ALL ELECTRICAL PURPOSES. By Francis Jehl. Fully illustrated. Price 10s. 6d. post free.

This work gives a concise account of the process of making High Grade and other Carbon for Electric Lighting, Electrolytic, and all other electrical purposes.

CONTENTS.

Chapter I.—Physical Properties of Carbon.
„ II.—Historical Notes.
„ III.—Facts concerning Carbon.
„ IV.—The Modern Process of Manufacturing Carbons.
„ V.—Hints to Carbon Manufacturers
„ VI.—A "New" Raw Material.
„ VII.—Gas Generators.
„ VIII.—The Furnace.
Chapter IX.—Estimation of High Temperatures.
„ X.—Gas Analysis.
„ XI.—On the Capital necessary for starting Carbon Works &c.
„ XII.—The Manufacture of Electrodes on a Small Scale.
„ XIII.—Building a Carbon Factory.
„ XIV.—Soot or Lamp Black.
„ XV.—Soot Factories.

Kershaw—THE ELECTRIC FURNACE IN IRON AND STEEL PRODUCTION. By John B. C. Kershaw, F.I.C. Fully illustrated. 8vo. Price 3s. 6d. nett.

Kilgour—*See* GEIPEL AND KILGOUR, page 9.

Lemström—ELECTRICITY IN AGRICULTURE AND HORTICULTURE. By Prof. S. Lemström. With illustrations. Price 3s. 6d. nett.

The late Dr. Lemström's work in connection with the Application of Electricity to Agriculture and Horticulture has attained world-wide recognition, and in the development, which this branch of Electrical Science and Application is undergoing Prof. Lemström's valuable early experiments prove of the greatest service. The book is circulating in all parts of the world, as it is realised that there are great possibilities in front of us in regard to this great question.

Livingstone—THE MECHANICAL DESIGN AND CONSTRUCTION OF GENERATORS. By R. Livingstone. *Now Ready.* Fully illustrated. Price 9s. nett, post free 9s. 6d.

The Author has dealt with the design of generators and motors from the mechanical point of view, in the hope that it will be of service to engineers in making clear the application of the principples of mechanics to the design of electrical machines.

In high speed machines it is essential that the rotors be designed from a mechanical point of view if success in operation is to be obtained, and the Author has dealt as fully as possible with this type of machine.

CONTENTS.—Chapter I. Pulleys, Bearings and Couplings.—II. Rotor Hubs and End Plates.—III.—Unbalanced Magnetic Pull.—IV. Shafts and Bearings (Slow Speed).—V. Alignment of Shafts.—VI. Stator Frames.—VII. Stresses in Rotors.—VIII. Poles and End Clamps.—IX. Field Coil Supports.—X. Rotor Bodies.—XI. Cylindrical Rotors.—XII. Shafts and Bearings (High Speed).—XIII. General Details.—XIV. Types of Rotors (High Speed).—Appendix.

Livingstone — THE MECHANICAL DESIGN AND CONSTRUCTION OF COMMUTATORS. By R. Livingstone. Fully illustrated. 6s. nett.

This book is intended principally for draughtsmen and engineers engaged in the design of electrical machinery, but it will also be found useful by students. . . . The two types dealt with represent the most general present-day practice in commutator construction, and will serve to show the principles involved in design.

Livingstone—LIVINGSTONE'S DIAGRAM FOR THE EASY CALCULATION OF SHAFT AND BEAM DEFLECTIONS. With fully worked out examples for use. On hard paper, price 2s. 6d. nett; by post, in tube, 2s. 10d. On card, 3s. nett; by post, in tube, 3s. 6d. 10 per cent. reduction on orders for 6 copies; 15 per cent. for 12 to 20 copies; 20 per cent. above 20 copies up to 50; beyond 50 33⅓ per cent.

Lodge—WIRELESS TELEGRAPHY.—SIGNALLING ACROSS SPACE WITHOUT WIRES. By Sir Oliver J. Lodge, D.Sc., F.R.S. New and Enlarged Edition. Very fully illustrated. Price 5s. nett, post free 5s. 3d.

The new edition forms a complete Illustrated Treatise on Hertzian Wave Work. The Full Notes of the interesting Lecture delivered by the Author before the Royal Institution, London, in June, 1894, form the first chapter of the book. The second chapter is devoted to the Application of Hertz Waves and Coherer Signalling to Telegraphy, while Chapter III. gives Details of other Telegraphic Developments. In Chapter IV. a history of the Coherer Principle is given, including Professor Hughes' Early Observations before Hertz or Branly, and the work of M. Branly. Chapters are also devoted to "Communications with respect to Coherer Phenomena on a Large Scale," the "Photo-Electric Researches of Drs. Elster and Geitel," &c.

Malcolm—THE THEORY OF THE SUBMARINE CABLE. By H. W. Malcolm, D.Sc. *Nearly Ready.*

The book is the outcome of a desire on the part of the Author to understand the phenomena which underlie the working of the submarine telegraph cable. The results of his investigations have appeared in The Electrician, but they are now brought together here, with much additional matter, consisting chiefly of the chapters on the Theory of the Submarine Telephone Cable, and it is hoped that they will prove useful as an introduction to the study of this important subject.

CONTENTS.

Chapter I. Mathematical Recapitulation.
„ II. The Fundamental Cable Constants.
„ III. Transient and Periodic Phenomena
„ IV. The Telegraphic Equation and its Periodic Solution.
„ V. The Methods of Loading Cables.
„ VI. Discontinuities and Reflexions.
„ VII. Alternating Current Measurements.
„ VIII. The Telegraphic Equation and its Transient Solution.
„ IX. The Part Played by the Signalling Apparatus.
Chapter X. Sending Phenomena and the Influence of Leaks.
„ XI. Signalling by Inverse Currents.
„ XII. Sine Wave Transmission.
„ XIII. Distortion and How it is Produced.
, XIV. Present-Day Methods of Overcoming Distortion.
„ XV. The Duplexed Cable.
„ XVI. The Loaded Telegraph Cable.

There is also a group of Appendices containing Data, Formulæ, &c.

Maurice—ELECTRIC BLASTING APPARATUS AND EXPLOSIVES, WITH SPECIAL REFERENCE TO COLLIERY PRACTICE. By Wm. Maurice, M.Nat.Assoc. of Colliery Managers, M.I.Min.E., A.M.I.E.E. Price 8s. 6d. nett.

The aim of this book is to prove itself a useful work of reference to Mine Managers, Engineers and others engaged in administrative occupations by affording concise information concerning the most approved kinds of apparatus, the classification and properties of explosives, and the best known means of preventing accidents in the use of them. The work gives not only an explanation of the construction and safe application of blasting appliances, the properties of explosives, and the difficulties and dangers incurred in daily work, but it also serves as an easy introduction to the study of electricity—without at least a rudimentary knowledge of which no mining official can now be considered adequately trained. Particular attention has been devoted to the problem of safe shot firing in coal mines.

Maurice—THE SHOT-FIRER'S GUIDE: A Practical Manual on Blasting and the Prevention of Blasting Accidents. By W. Maurice, M.I.M.E., A.I.E.E. 3s. 6d. nett.

Phillips—THE BIBLIOGRAPHY OF X-RAY LITERATURE AND RESEARCH. Edited by C. E. S. Phillips. With an Historical Retrospect and a Chapter, "Practical Hints," on X-Ray work by the Editor. Price 3s.

Raphael—THE LOCALISATION OF FAULTS IN ELECTRIC LIGHT MAINS. By F. Charles Raphael. *New Edition Now Ready.* 8s. 6d. nett, post free 9s.

Although the localisation of faults in telegraph cables has been dealt with fully in several hand-books and pocket-books, the treatment of faulty electric light and power cables has never been discussed in an equally comprehensive manner. The conditions of the problems are, however, very different in the two cases; faults in telegraph cables are seldom localised before their resistance has become low compared with the resistance of the cable itself, while in electric light work the contrary almost always obtains.

CONTENTS:—

Chapter I., Introductory; Chapter II., Insulation Testing of Low-pressure Networks during Working; Chapter III., Insulation Testing of High-pressure Mains during Working; Chapter IV., Loop, Methods of Fault Localising; Chapter V., Fall of Potential Methods; Chapter VI., Induction Methods; Chapter VII., General Notes as to the Application of Methods; Chapter VIII., Discontinuities and Short Circuits; Chapter IX., Tramway Feeders; Chapter X., Miscellaneous Methods and Particular Cases; Chapter XI., Duplicate Feeders and Automatic Systems of Mains Protection; Chapter XII., Proofs of Formula, &c.

Raymond-Barker—THE TWO-TONE VIBRATING TRANSMITTER AND CABLE INDUCTIVE SIGNALLING. By Edward Raymond-Barker, M.I.E.E. Fully illustrated. 1s. nett; by post, 1s. 3d.

This book gives a Description of a Novel Telegraphic Apparatus and Equal-Time-Element System for Electro-Vibrating Telegraphic Working.

Robinson and Warrilow—"THE ELECTRICIAN" WIREMAN'S POCKET-BOOK AND ELECTRICAL CONTRACTOR'S HANDBOOK. Compiled by A. W. Robinson and W. E. Warrilow, A.M.I.E.E. Fully Illustrated. 5s. nett, by post 5s. 3d.

The following is a brief synopsis of the contents: Systems of Wiring: Wiring Diagrams, Typical Interior and Exterior Installations (Residences, Shops, Churches, Chapels, Public Buildings, Exhibitions, &c.): Temporary Wiring and Illumination: Testing and Testing Instruments; Wiring Rules: Notes and Data on Illuminating Engineering: Metal Filament Lamps: Shades and Reflectors: Lanterns and Special Fittings; Arc Lamps and Accessories: Illumination Curves, &c.: Small Motors for Trade and Domestic Purposes: Erection and Maintenance of Steam, Gas, Paraffin and Petrol Engines and Water Turbines: Batteries and Switchgear: General Notes on Running of Plant, &c.

Rowe—ELECTRIC LIFTS AND HOISTS. By G. Rowe, M.I.E.E. *In preparation.*

Sayers—BRAKES FOR TRAMWAY CARS. By Henry M. Sayers, M.I.E.E. Illustrated. 2s. 6d. nett.

Shaw—A FIRST-YEAR COURSE OF PRACTICAL MAGNETISM AND ELECTRICITY. By P. E. Shaw, B.A., D.Sc., Senior Lecturer and Demonstrator in Physics at University College, Nottingham. Price 2s. 6d. nett; 2s. 9d. post free.

The many small books on Elementary Practical Physics, which are suitable for schools or or university intermediate students, all assume in the student a knowledge of at least the rudiments of algebra, geometry, trigonometry and mechanics. There is, however, a large and growing class of technical students who have not even this primitive mathematical training, and who cannot, or will not, acquire it as a foundation for physical science. They enter the laboratory and ask for an introduction to such fundamentals of the subject as most affect the arts and crafts. On the one hand, mere qualitative experiments are of little use to these (or any other) students; on the other hand, mathematical expressions are stumbling blocks to them. In attempting to avoid both these evils, I have sought to make the experimental work as quantitative as possible, yet to avoid mathematics. There are three introductory exercises, six exercises on magnetism, twenty on electricity and six on the applications.

Soddy—RADIO-ACTIVITY: An Elementary Treatise from the Standpoint of the Disintegration Theory. By Prof. Fredk. Soddy, M.A. Fully Illustrated, and with a full Table of Contents and extended Index. 4s. nett.

TEMPERATURE COEFFICIENTS OF "CONDUCTIVITY" COPPER. Strongly bound in cloth. 2s. 6d. nett.

The compilers (Messrs. CLARK, FORDE, TAYLOR and ERSKINE-MURRAY, the well-known consulting engineers) have made fresh investigations of the temperature coefficient over the range of temperature to which Cables are usually exposed, and the results of their investigations are now published.

TABLE I. gives the reist. at different temperatures when the Res. at 32°F.=1. TABLE II. gives the resist. at different temperatures when the Res. at 60°F.=1. TABLE III. gives the resist. at different temperatures when the Res. at 75°F.=1; and TABLE IV. gives the log. reciprocals of coefficients in Table III.

SHEET TABLE SHOWING LOG. RECIPROCALS OF COEFFICIENTS FOR COPPER RESISTANCES. At different temperatures from 32°F. to 84·9°F. On strong cardboard, price 6d. nett.

Wade—SECONDARY BATTERIES: THEIR MANUFACTURE AND USE. By E. J Wade. New Edition, revised by W. R. Cooper. Price 12s. 6d. nett. by post 13s. *Ready about May*, 1916.

In this work the Author deals briefly with the Theory and very fully with the Chemistry, Design, Construction and Manufacture of Secondary Batteries or Accumulators. Prospectuses, post free, on application.

The scope of Mr. Wade's important work covers the whole class of apparatus embraced in the theory, construction and use of the secondary battery. The major portion of the book treats the accumulator purely from the point of view of an appliance which fulfils an important and definite purpose in electrical engineering practice, and whose manufacture, use and properties must be understood just as fully as those of a generator or a transformer. The concluding chapter (X.) gives a complete description of all modern electrical accumulators. The book contains 265 illustrations and a very copious index.

Warrilow—*See* ROBINSON AND WARRILOW, p. 12.

Wilkinson—SUBMARINE CABLE-LAYING AND REPAIRING. By H. D. Wilkinson. M.I.E.E., &c. Over 400 pages and 200 specially drawn illustrations. *New Edition in preparction.*

This work describes the procedure on board ship when removing a fault or break in a submerged cable and the mechanical gear used in different vessels for this purpose; and considers the best and most recent practice as regards the electrical tests in use for the detection and localisation of faults, and the various difficulties that occur to the beginner. It gives a detailed technical summary of modern practice in Manufacturing, Laying, Testing and Repairing a Submarine Telegraph Cable. The testing section and details of 'boardship practice have been prepared with the object and hope of helping men in the cable services who are looking further into these branches.

Woods—ÆTHER: A Theory of the Nature of Æther and of its Place in the Universe. By Hugh Woods, M.D., M.A.O., B.Ch., B.A. 8vo. Bound strong cloth. Price 4s. 6d. nett, post free 4s. 9d.

Young—ELECTRICAL TESTING FOR TELEGRAPH ENGINEERS. By J. Elton Young. Very fully illustrated. *New Edition now ready.* 10s. 6d. nett.

This book embodies up-to-date theory and practice in all that concerns everyday work of the Telegraph Engineer.

The Contents include:

Chapter I.—Remarks on Testing Apparatus,
„ II.—Measurements of Current, Potential & Battery Resistance.
„ III.—Natural and Fault Current.
„ IV.—Measurement of Conductor Resistance.
„ V.—Measurement of Insulation Resistance.
„ VI.—Corrections for Conduction and Insulation Tests.
Chapter VII.—Measurement of Inductive Capacity.
„ VIII.—Localisation of Disconnections.
„ IX.—Localisation of Earth and Contacts.
„ X.—Corrections of Localisation Tests.
„ XI.—Cable Testing during Manufacture, Laying and Working.
„ XII.—Submarine Cable Testing during Localisation and Repairs.

MANUFACTURE OF ARC LIGHT CARBONS. A practical Guide to the Establishment of a Carbon Manufactory. *New Edition.* Fully illustrated. Price 2s. 6d , post free, 2s. 9d.

THE INTERNATIONAL TELEGRAPH CONVENTION AND SERVICE REGULATIONS. (Lisbon Revision, 1908.) The complete Official French Text with English Translation in parallel columns, by C. E. J. Twisaday (India Office, London), Geo. R. Neilson (Eastern Telegraph Co., London), and officially revised by permission of H.B.M. Postmaster-General. Cloth (foolscap folio), 6s. nett; (demy folio), 8s. 6d. nett, or foolscap, interleaved ruled paper, 8s. 6d. nett. Postage 6d.; abroad, 9d.

INTERNATIONAL RADIO-TELEGRAPH CONVENTION AND SERVICE REGULATIONS (LONDON, 1912). Price 5s. nett, post free 5s. 6d.

INTERNATIONAL RADIO-TELEGRAPH CONFERENCE, BERLIN, 1903. Full Report of the Proceedings at the Conference. Translated into English by G. R. Neilson. Officially accepted by the Post Office Authorities. Bound Cloth, 6s. postage per copy 6d., abroad 1s.

INTERNATIONAL RADIO-TELEGRAPH CONFERENCE, BERLIN, October-November, 1906, with the International Radio-Telegraphic Convention, Additional Undertaking, Final Protocol and Service Regulations in French and English. Officially accepted Translation into English of the complete Proceedings at this Conference. This translation, which has been made by Mr. G. R. Neilson, is published under the authority of H.B.M. Postmaster-General, and is accepted as official by the British Government Departments concerned. Strongly bound in cloth, 15s. nett; leather, 19s. nett. (lettered free). Postage per copy: U.K. 6d.; abroad 1s. 6d.

ELECTRICITY IN MINES.—Under the new Rules and Regulations concerning the Use of Electricity in Mining Operations, it is compulsory that directions for the effective Treatment of Cases of Apparent Death from Electric Shock be conspicuously placed in certain prescribed positions in the Mines.

A set of these DIRECTIONS, with illustrations showing the method of application accompanied by PRECAUTIONS to be adopted to prevent danger from the electric current and INSTRUCTIONS for dealing with BROKEN ELECTRIC WIRES, is now ready.

PRICES :—On paper,	17in. by 12¼in.	4d. each ;	3s. 6d. per dozen.
On card,	ditto	8d. ,,	6s. 6d. ,,

Post free or carriage paid in each case.

"THE ELECTRICIAN" PRIMERS. *See* complete list on p. 8.

A further volume of "The Electrician" Primers is in the press. The new volume will deal exclusively with practical applications of electricity to industrial operations.

Portraits of Famous Men of Science and Industry.—

"ELECTRICIAN" SERIES OF STEEL-PLATE PORTRAITS.

ANDERSON, SIR JAMES.
AYRTON, PROF. W. E.
CROMPTON, COL. R. E. B.
CROOKES, SIR WILLIAM.
*FARADAY, MICHAEL.
FIELD, CYRUS W.
HELMHOLTZ, HERMANN VON.
HERTZ, HEINRICH.
HOPKINSON, DR. JOHN.
KELVIN, LORD.
LODGE, SIR OLIVER.
MANCE, SIR HENRY C.
PATEY. C. H B.
PENDER, SIR JOHN.
PREECE, SIR W. H.
RAYLEIGH, LORD.
SIEMENS, ALEXANDER.
SIEMENS, WERNER VON.
SIEMENS, SIR WILLIAM.
*SMITH, WILLOUGHBY.
STURGEON, WILLIAM.
SWAN, SIR JOSEPH WILSON.
THOMSON, PROF. SIR J. J.
* 1s. extra.

Price 1s. each. Post free on Roller, 1s. 2d. India mounts, 1s. extra. Or framed in neat Black Pillar or Brown Ornamental Frames, 4s. 6d. ; carriage paid (U.K.) 5s. If with mounts 1s. extra.

Price £1. 5s., *in Sepia or Black ; in very Massive Frame*, £2. 5s.
A Handsome Plate Reproduction of ROBERT DUDLEY'S famous Painting of

THE "GREAT EASTERN"

(By permission of the Executors of the late Sir JAMES ANDERSON.)

The subject measures 24 in. by 17 in., and is India mounted on fine etching boards, the mount measuring 27 in. by 21 in. The entire plate measures 36 in. by 27 in.

Another fine view of the grand old ship, by the same artist, at the same prices as above, is now available.

PHYSICAL SOCIETY OF LONDON.

The "PROCEEDINGS" of the Physical Society of London.

Published Bi-Monthly from December to August. Can be obtained from the Publishers, "THE ELECTRICIAN" PRINTING AND PUBLISHING CO. (LTD.), 1, 2 & 3, Salisbury-court, Fleet-street, London, from whom all Publications of the Society are obtainable. Price of "Proceedings" to Non-Fellows, 4s. nett per part, post free 4s. 3d. Annual Subscription, 20s. post free, payable in advance.

Strong cloth cases for binding the "Proceedings," price 1s. 9d. each, post free.

The "PROCEEDINGS," of the Physical Society can be obtained at the following prices :

Vol. I. (3 parts), bound cloth, 15s. Vols. II., IV., V., XXIII., XXV., XXVI. & XXVII. (5 parts each), bound cloth, 23s. Vols. III., VI. to XII. & XXII. (4 parts each), bound cloth, 19s. Vol. XIII. (13 parts, each containing Abstracts), bound cloth (without Abstracts), 47s. Vols. XIV. & XV. (12 parts each, containing Abstracts), bound cloth (without Abstracts), 23s. Vols. XVI. & XIX. (8 parts each), bound cloth, 35s. Vols. XVII, XVIII. & XXI. (7 parts each), bound cloth, 31s. Vols. XX. & XXIV. (6 parts), bound cloth, 27s.

Most of the Parts can be purchased separately, price 4s., by post 4s. 3d.

Fellows can obtain the *Proceedings* (in parts) for their personal use at half the above prices.

These prices do not include postage or carriage.

ABSTRACTS OF PHYSICAL PAPERS from Foreign Sources :

Vols. I. (1895), II. (1896), and III. (1897), 15s. each : to Fellows, 7s. 6d. each.

Other Publications of the Physical Society are :

(1) THE SCIENTIFIC PAPERS OF THE LATE SIR CHARLES WHEATSTONE, F.R.S.
Demy 8vo., cloth. Price, 8s. (to Fellows, 4s.)
Uniform with the above.

(2) THE SCIENTIFIC PAPERS OF JAMES PRESCOTT JOULE, D.C.L., F.R.S.
Vol. I., 4 Plates and Portrait, price 12s. (to Fellows, 6s.). Vol. II., 3 Plates, price 8s. (to Fellows, 4s.

(3) PHYSICAL MEMOIRS.
PART I.—VON HELMHOLTZ, On the Chemical Relations of Electrical Currents. Pp. 110. Price 4s. (to fellows, 2s.).
PART II.—HITTORF, On the Conduction of Electricity in Gases ; PULUJ, On Radiant Electrode Matter. Pp. 222. Price 8s. (to Fellows, 4s.).
PART III.—VAN DER WAALS, On the Continuity of the Liquid and Gaseous States of Matter. Pp. 164. Price 8s. (to Fellows, 4s.).

(4) JEANS, J. H. Report on Radiation and the Quantum Theory. 6s. (to Fellows, 3s.). Bound Cloth, 8s. 6d. ; to Fellows, 5s. 6d.

(5) BLAKESLEY, T. H. A Table of Hyperbolic Sines and Cosines. 1s. 6d. (to Fellows, 9d.).

(6) LEHFELDT. R. A. A List of Chief Memoirs on the Physics of Matter. 2s. (to Fellows, 1s.)

ELECTRICITY SUPPLY TABLES.—Useful and Complete Group of Statistics, &c., for Local Authorities, Supply Station Engineers, Consulting and Contracting Engineers, Manufacturing and Supply Houses, &c.

PRE-WAR FORM OF TABLES.—(These Tables are issued in a modified form during the War.)

The 1916 Edition of the important Statistics and Data relating to **Electricity Supply in the United Kingdom** (which have been published annually since 1887) are now obtainable (in a modified form), price **3s.** nett, post free, **3s. 6d.**

The Tables of **Colonial (and certain Foreign) Electricity Supply, Power and Traction Stations** are also obtainable (in the usual form), price **2s. 6d.** nett, post free **2s. 9d.** The two set of tables are supplied price **4s. 6d.** nett, post free **4s. 10d.**

TABLE I.—Electricity Supply Undertakings of the United Kingdom, with no Tramway Load, containing particulars of the System employed, Voltage, Frequency, Connections, Number of Consumers, &c.

TABLES Ia and II.—Towns taking Electricity Supply "In Bulk," giving full particulars in each case; and **Electricity Works Supplying both Lighting and Tramways,** containing similar information to Table I. for Stations with a Combined Lighting and Tramway Load.

TABLE III.—Electric Power Undertakings of the United Kingdom, containing a List of the various Power Companies, particulars of the Systems employed and Areas covered, and Technical Information with regard to the Stations, Mains, Sub-stations, &c.

TABLES IV. V. and VI.—Electric Tramways and Railways of the United Kingdom including those with their own Power Houses and those which buy their Power. For the former full particulars are given as to Power Station Equipment, and in both cases information is included as to Track, Line Equipment, Feeders, Rolling Stock, &c.

TABLES VII. and VIII.—Colonial and Foreign Electricity Supply Works, giving technical particulars of the Generating Plant, System of Distribution, Periodicities, Voltages. Connections to Mains, &c., of the principal Electricity Supply Undertakings of the Colonies, Central and South America, Japan, &c., &c., and **Colonial and Foreign Electric Tramways,** giving particulars of Power House Equipment, Track, Line Equipment, Feeders, Rolling Stock, &c.

Post free for 6s. 6d.

This complete Set of **"ELECTRICIAN" TABLES, &c.,** forms the most Complete and Useful Group of Statistics ever prepared for Central Stations, Electrical Engineers' and Contractors' Offices, Local Authorities, Manufacturing and Supply Houses, &c., and gives at a glance all information likely to be required in the preparation of Technical Data, Statistical Statements, &c. The information is prepared in a form which enables comparison to be readily made.

"THE ELECTRICIAN" ELECTRICITY SUPPLY, POWER AND HEATING BOOKLETS.

A number of Booklets and Leaflets dealing with the various Applications of Electricity to Local Consumers has been prepared by Mr. W. E. Warrilow, A.M.I.E.E., and these have had a large circulation. They are being added to from time to time, and the list available, includes the following:—

INDUSTRIAL POWER SERIES.

1. Electric Power in Woodworking Shops.
2. Electric Power in Engineers' Workshops.
3. Electric Power in Printing Works.
4. Electric Passenger and Goods Lifts.
5. Electric Power in Bakeries.
6. Portable Electric Tools and Appliances.
7. Ten Minutes with the Electric Motor (C.C.).
8. Ten Minutes with the Three-Phase Motor.
9. Electric Organ Blowing.
10. What the Small Motor Can Do.

LIGHT AND HEAT SERIES.

1. White and Golden Lights (Flame Arcs).
2. Electric Heat in the Home.
3. Electricity in the Kitchen.
4. Electric Signs.
5. Electric Fans.

These Booklets are supplied at the prices below set out:—

Prices for the Series of Copyright Booklets.

	£ s. d.		£ s. d.	
50 copies	0 10 0	500 copies	3 10 0	Net assorted. If of any one Booklet less 5 per cent.
100 ,, ...	0 17 6	750 ,, ...	4 10 0	
250 ,, ...	1 17 6	1,000 ,, ...	5 5 0	

If ordered in quantities of not less than 250 (assorted or otherwise), the front and back pages of the Booklets (whether white paper or coloured) can be printed with text or illustrations supplied by the Purchaser at the prices following:—

	s. d.		s. d.
250 copies	10 9 extra.	1,000 copies	15 6 extra.
500 ,, ...	12 6 ,,	1,500 ,, ...	17 9 ,,
750 ,, ...	14 0 ,,	2,000 ,, ...	20 0 ,,

Or Purchasers' own covers can be attached to the pamphlets (printed to cut to the booklet size), at a small charge for the work involved. In this way any printed matter can be included with the Booklets.

Estimates for any desired printed matter in connection with the Booklets, either bound in or separately, will be furnished free on request.

Special text and illustrations for pamphlet literature on any electrical subject will be provided promptly on application to the Industrial Department, "The Electrician" Printing & Publishing Co., Ltd., 1, 2 and 3, Salisbury Court, Fleet Street, London, E.C. (Telephone: City 4698 and 4699.)

SELECTED LIST OF STANDARD WORKS

For Electrical and Mechanical Engineers, Students, &c.

Aitken—MANUAL OF THE TELEPHONE. *See p.* 3.

Allen—PHOTO ELECTRICITY. By H. S. Allen. 7s. 6d. nett.

Allen and Moore—TEXT BOOK OF PRACTICAL PHYSICS. By H. S. Allen, M.A., and H. Moore, B.Sc. 8s. 6d. nett.

Anderson—BOILER FEED WATER. *See p.* 3.

Atkins—COMMON BATTERY TELEPHONY SIMPLIFIED. *See p.* 3. [*See p.* 3.

Atkins—THE PRINCIPLES OF AUTOMATIC TELEPHONY—

Austin—SINGLE-PHASE ELECTRIC RAILWAYS. By E. Austin. 21s. nett.

Ayrton—PRACTICAL ELECTRICITY. By Prof. W. E. Ayrton. Revised and largely re-written by Prof. T. Mather. 9s. nett.

Ayrton (Mrs.)—THE ELECTRIC ARC. *See p.* 3.

Barham—THE DEVELOPMENT OF THE INCANDESCENT ELECTRIC LAMP. By G. Basil Barham. 5s.

Barr—PRINCIPLES OF DIRECT CURRENT ELECTRICAL ENGINEERING. By Jas. R. Barr. 10s. nett.

Bateman—ELECTRICAL AND OPTICAL WAVE MOTION. By H. Bateman. 7s. 6d. nett.

Batstone—ELECTRIC LIGHT FITTINGS. By S. C. Batstone. 5s. nett.

Beaumont—THE STEAM ENGINE INDICATOR AND INDICATOR DIAGRAMS. *See p.* 4.

Bloch—THE SCIENCE OF ILLUMINATION. By Dr. L. Bloch. Translated by W. C. Clinton, B.Sc. 6s. nett.

Blok—THE ELEMENTARY PRINCIPLES OF ILLUMINATION AND ARTIFICIAL LIGHTING. By Arthur Blok. 3s. 6d. nett.

Bohle—ELECTRICAL PHOTOMETRY AND ILLUMINATION. By H. Bohle. 10s. 6d. nett.

Bohle and Robertson—TRANSFORMERS. By H. Bohle and D. Robertson. 25s. nett.

Brew—THREE-PHASE DISTRIBUTION. By W. Brew. 7s. 6d. nett.

Bright—SUBMARINE TELEGRAPHS; Their History, Construction and Working. By Charles Bright, F.R.S.E., M.I.C.E. £3. 3s. nett.

Broughton—ELECTRIC CRANES. *See p.* 4.

Burch—ELECTRIC TRACTION FOR RAILWAY TRAINS. By Edward P. Burch. 21s nett.

Burns—ELECTRICAL PRACTICE IN COLLIERIES. By D. Burns, M.I.M.E. Fourth Edition, 7s. 6d. nett.

Bursill—THE PRINCIPLES AND PRACTICE OF ELECTRIC WIRING. By A. Bursill. 3s. nett.

Chalkley—DIESEL ENGINES FOR LAND & MARINE WORK. By A. P. Chalkley. 4th Ed. 8s. 6d. nett.

Christie—ELECTRICAL ENGINEERING: THE THEORY AND CHARACTERISTICS OF ELECTRICAL CIRCUITS AND MACHINERY. By C. V. Christie. 17s. nett.

Clerk—THE GAS, PETROL AND OIL ENGINE. By Dugald Clerk. Vol. I. 12s. 6d. nett. Vol. II.—Practice. By D. Clerk and G. A. Burls. 25s. nett.

Clewell—FACTORY LIGHTING. By C. E. Clewell. 8s. 6d. nett.

Codd—DYNAMO LIGHTING FOR MOTOR CARS. By M. A. Codd. 2s. 6d. nett.

Cohen—FORMULÆ AND TABLES FOR THE CALCULATION OF ALTERNATING CURRENT PROBLEMS. By L. Cohen. 12s. 6d. nett.

Collins—MANUAL OF WIRELESS TELEGRAPHY AND TELEPHONY. By A. F. Collins. Third Edition, 6s. 6d. nett.

Collins—THE DESIGN AND CONSTRUCTION OF INDUCTION COILS. By A. F. Collins. 13s. 6d. nett.

Connan—SWITCHBOARD MEASURING INSTRUMENTS FOR CONTINUOUS AND POLYPHASE SYSTEMS. By John C. Connan. 5s. nett.

Cooper—PRIMARY BATTERIES. *See p.* 4.

Cooper—*See* "THE ELECTRICIAN" PRIMERS, page 8.

Cooper—A TREATISE ON ELECTRO-METALLURGY. By By W. G. McMillan. Third edition. Revised by W. R. Cooper. 12s. 6d. nett.

Coyle and Howe—ELECTRIC CABLES. By D. Coyle and F. J. O. Howe. 15s. nett.

Cramp—CONTINUOUS CURRENT MACHINE DESIGN. By W. Cramp. 5s. nett.

Crotch—TELEGRAPHIC SYSTEMS AND OTHER NOTES. By A. Crotch. 5s. nett.

Crotch—THE HUGHES AND BAUDOT TELEGRAPHS. By A. Crotch. 1s. 6d. nett.

Cunningham—RELATIVITY AND THE ELECTRON THEORY By E. Cunningham, M.A. 4s. nett.

Davidge and Hutchinson—TECHNICAL ELECTRICITY. By H. J. Davidge and R. W. Hutchinson. 5s. 6d. nett.

Dawson—*See* ELECTRIC TRACTION ON RAILWAYS, page 4.

Devey—MILL AND FACTORY WIRING. By R. G. Devey. 2s. nett.

Drysdale—THE FOUNDATIONS OF ALTERNATE-CURRENT THEORY. By Dr. C. V. Drysdale. 8s. 6d. nett.

Drysdale and Jolley—ELECTRICAL MEASURING INSTRUMENTS; THEIR DESIGN, CONSTRUCTION AND APPLICATION. *See p.* 5.

Dwight—CONSTANT VOLTAGE TRANSMISSION. By H. B. Dwight. 5s. 6d. nett.

Dwight—TRANSMISSION LINE FORMULAS FOR ELECTRICAL ENGINEERS AND STUDENTS. By H. E. Dwight. 8s. 6d. nett.

Edgcumbe—INDUSTRIAL ELECTRICAL MEASURING INSTRUMENTS. By Kenelm Edgcumbe. 8s. nett.

Elder—SWITCHES AND SWITCHGEAR. By Prof. P. Elder. Translated by P. L. Laubach. 15s. nett.

Ellis—ELEMENTARY PRINCIPLES OF ALTERNATING-CURRENT DYNAMO DESIGN. By A. G. Ellis. 12s. nett.

Erskine-Murray—A HANDBOOK OF WIRELESS TELEGRAPHY. By J. Erskine-Murray, D.Sc. Fifth Edition. 10s. 6d. nett.

Erskine-Murray—WIRELESS TELEPHONY. By Ernst Ruhmer. Translated by J. Erskine-Murray, D.Sc. 10s. 6d. nett.

Ewing—MAGNETIC INDUCTION IN IRON AND OTHER METALS *See p.* 5.

Ewing—THE STEAM ENGINE AND OTHER HEAT ENGINES. By Sir J. A. Ewing, F.R.S. Third edition. 15s.

Ferguson—THE ELEMENTS OF ELECTRICAL TRANSMISSION. By O. J. Ferguson. 15s. nett.

Field—THE PRINCIPLES OF ELECTRO-DEPOSITION. By S. Field. 6s. nett.

Fisher and Darby—STUDENTS' GUIDE TO SUBMARINE CABLE TESTING. *See p.* 6.

Fleming.—*See* Works of Dr. J. A. Fleming in "The Electrician" Series, pages 6 and 7.

Fleming — AN ELEMENTARY MANUAL OF RADIO-TELEGRAPHY AND RADIOTELEPHONY. By Prof. J. A. Fleming, D.Sc. 7s. 6d. nett..

Fleming—THE PRINCIPLES OF ELECTRIC WAVE TELEGRAPHY. By Prof. J. A. Fleming, M.A., D.Sc. 2nd Edition. 28s. nett.

Fleming—THE WONDERS OF WIRELESS TELEGRAPHY. By Prof. J. A. Fleming. 3s. 6d. nett.

Fleming—PROPAGATION OF ELECTRIC CURRENTS IN TELEPHONE AND TELEGRAPH CONDUCTORS. By Prof. Fleming. 8s. 6d. nett.

Fleming—THE WONDERS OF WIRELESS TELEGRAPHY. By Prof. J. A. Fleming, M.A., D.Sc., F.R.S. 3s. 6d. nett.

Fleming and Johnson—INSULATION AND DESIGN OF ELECTRICAL WINDINGS. By A. P. M. Fleming and R. Johnson. 7s. 6d. net.

Foster and Porter—ELEMENTARY TREATISE ON ELECTRICITY AND MAGNETISM. By G. C. Foster and A. W. Porter. 3rd Ed. 10s. 6d. nett.

Fournier—THE ELECTRONIC THEORY. By E. E. Fournier 5s. nett.

Fowle—STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS. By F. B. Fowle. 21s. nett.

Franklin—ELECTRIC LIGHTING AND MISCELLANEOUS APPLICATIONS OF ELECTRICITY. By W. S. Franklin. 11s net.

Franklin and Esty—DYNAMOS AND MOTORS. By W. S. Franklin and Wm. Esty. 17s. 6d. nett.

Franklin and Esty—THE ELEMENTS OF ELECTRICAL ENGINEERING. By Wm. S. Franklin and Wm. Esty. 18s. 6d. nett. [5s. nett.

Frith—ALTERNATING-CURRENT DESIGN. By J. Frith.

Gaster and Dow—MODERN ILLUMINANTS AND ILLUMINATING ENGINEERING. By L. Gaster and J. S. Dow.

Gear and Williams—AMERICAN ELECTRIC CENTRAL STATION DISTRIBUTION SYSTEMS. By H. Gear and P. F. Williams. 12s. nett.

Gerhardi—ELECTRICITY METERS: Their Construction and Management. By C. H. W. Gerhardi. *See p.* 9.

Glazebrook—ELECTRICITY AND MAGNETISM. By R. T. Glazebrook, M.A., F.R.S. 7s. 6d.

Glover—CONSUMERS' ACCOUNTS AND METER DEPART MENT ROUTINE. By A. C. Glover. 5s. nett.

Gore—*See* Works of Dr. Gore in "The Electrician" Series, p. 9.

Gray—ELECTRIC MACHINE DESIGN. By A. Gray. 17s. nett.

Gray—THEORY AND PRACTICE OF ABSOLUTE MEASUREMENTS IN ELECTRICITY AND MAGNETISM. By Prof Andrew Gray, M.A. F.R.S.E. In two Vols., crown 8vo. Vol. I., 12s. 6d. Vol. II., in two parts, 25s.

Groth—WELDING AND CUTTING METALS BY AID OF GASES OR ELECTRICITY. By Dr. L. A. Groth. 10s. 6d. nett.

Hadley—MAGNETISM AND ELECTRICITY FOR STUDENTS. By H. E. Hadley. 6s. nett.

Hall—ELEMENTARY THEORY OF ALTERNATE-CURRENT WORKING. By Capt. G. L. Hall, R.E. 3s. 6d. nett. *See p.* 9.

Harding—ELECTRIC RAILWAY ENGINEERING. By C. F. Harding. 12s. 6d. nett.

Haslam—ELECTRICITY IN FACTORIES AND WORKSHOPS. By A. P. Haslam. 7s. 6d. nett.

Hausmann—TELEGRAPH ENGINEERING. By Erich Hausmann Sc.D. 12s. 6d. nett.

Havelock—ELECTRIC WIREMEN'S WORK. By J. H. Havelock. 5s. nett.

Hawkhead and Dowsett—HANDBOOK OF TECHNICAL INSTRUCTION FOR WIRELESS TELEGRAPHISTS. By J. C. Hawkhead and H. M. Dowsett. 3s. 6d. nett.

Hawkins and Wallis—DYNAMO, THE: Its Theory, Design and Manufacture. By C. C. Hawkins and F. Wallis. Fifth Edition. Two Vols., 21s. nett.

Hay—ELECTRICAL DISTRIBUTING NETWORKS AND TRANSMISSION LINES. By A. Hay, D.Sc. 10s. 6d. nett.

Hay—ALTERNATING CURRENTS: Their Theory, Generation, and Transformation. By A. Hay, D.Sc. Third Edition. 6s. nett.

Hay—AN INTRODUCTORY COURSE OF CONTINUOUS-CURRENT ENGINEERING. By A. Hay, D.Sc. 2nd Edition. 6s. 6d. nett.

Henderson—PRACTICAL ELECTRICITY AND MAGNETISM. By Dr. John Henderson. 7s. 6d.

Hobart — DESIGN OF POLYPHASE GENERATORS AND MOTORS. By H. M. Hobart. 12s. 6d. nett.

Hobart—ELECTRIC MOTORS. By H. M. Hobart. 2nd Ed. 18s. nett.

Hobart—ELECTRICITY. By H. M. Hobart. 6s. nett.

Hobart—HEAVY ELECTRICAL ENGINEERING. By H. M. Hobart. 16s. nett.

Hobart—THE ELECTRIC PROPULSION OF SHIPS. By H. M. Hobart. 5s. nett.

Hobart—A DICTIONARY OF ELECTRICAL ENGINEERING. By H. M. Hobart. Two Vols., 35s. nett

Hobart—ELECTRIC TRAINS. By H. M. Hobart. 6s. nett.

Hobart—STATIC-TRANSFORMERS. By H. M. Hobart. 6s. nett.

Hobart—BARE ALUMINIUM CABLES. By H. M. Hobart. 2s. 6d.

Hobart and Ellis — HIGH-SPEED DYNAMO ELECTRIC MACHINERY. By H. M. Hobart and A. G. Ellis. 25s. 6d. nett.

Hobart and Ellis—ARMATURE CONSTRUCTION. By H. M. Hobart and A. G. Ellis. 15s. nett.

Holt—TRAMWAY TRACK CONSTRUCTION AND MAINTENANCE. By R. Bickerstaffe Holt. 10s. 6d.

Hopkins—TELEPHONE LINES AND THEIR PROPERTIES By Prof. W. J Hopkins. 6s.

Horstmann and Tousley—MODERN ILLUMINATION, THEORY AND PRACTICE. By H. C. Horstmann and V. H. Tousley. 8s. 6d. nett.

Houstoun—STUDIES IN LIGHT PRODUCTION. *See page* 10.

Houstoun—A TREATISE ON LIGHT. By R. A. Houstoun, M.A. 7s. 6d. nett.

Hughes—PHOTO-ELECTRICITY. By Prof. A. Ll. Hughes. [6s. nett.

Hutchinson—LONG DISTANCE ELECTRIC POWER TRANSMISSION. By R. W. Hutchinson, Junr. 12s. 6d. nett.

Jackson—ELECTRIC CAR MAINTENANCE. By W. Jackson. 12s. 6d. nett.

Jansky—ELECTRICAL METERS. By C. M. Jansky. 10s. 6d. nett.

Jeans—MATHEMATICAL THEORY OF ELECTRICITY AND MAGNETISM. By J. H. Jeans, F.R.S. Second Edition. 15s. nett.

Jeans—REPORT ON RADIATION AND THE QUANTUM THEORY. By J. H. Jeans, M.A., F.R.S. 6s. *See p.* 15.

Jervis-Smith—DYNAMOMETERS. By Rev. F. J. Jervis-Smith, F.R.S. 14s. nett.

Jolley—*See* DRYSDALE AND JOLLEY, p. 5.

Jude and Satterly—MATRICULATION MAGNETISM AND ELECTRICITY. By R. H. Jude and J. Satterly. 4s. 6d.

Kapper—OVERHEAD TRANSMISSION LINES AND DISTRIBUTING CIRCUITS; their Design and Construction. By F. Kapper. Translated by P. F. Friedlaender. 16s. nett.

Karapetoff.—EXPERIMENTAL ELECTRICAL ENGINEERING. By V. Karapetoff. 25s. 6d. nett.

Kaye—X-RAYS; AN INTRODUCTION TO THE STUDY OF RONTGEN RAYS. By Dr. G. W. C. Kaye. 5s. nett.

Kelsey—CONTINUOUS CURRENT DYNAMOS AND MOTORS AND THEIR CONTROL. By W. R. Kelsey. Second Edition. 7s. 6d. nett.

Kempe—HANDBOOK OF ELECTRICAL TESTING. By H. R. Kempe. 18s. nett.

Kennelly—APPLICATION OF HYPERBOLIC FUNCTIONS TO ELECTRICAL ENGINEERING PROBLEMS. By Dr. A. E. Kennelly. 6s. nett.

Kershaw—THE ELECTRIC FURNACE IN IRON AND STEEL PRODUCTION. By J. B. C. Kershaw. 3s. 6d. nett. *See* also p. 10.

Kershaw—ELECTRO-METALLURGY. By John B. C. Kershaw. 6s. nett.

Kershaw—ELECTRO-THERMAL METHODS OF IRON AND STEEL PRODUCTION. By J. B. C. Kershaw. 8s. 6d. nett.

Kingsbury—THE TELEPHONE AND TELEPHONE EXCHANGES; their Invention and Development. By J. E. Kingsbury. 12s. 6s. nett.

Koester—HYDRO-ELECTRIC DEVELOPMENTS AND ENGINEERING. By Frank Koester. 21s. nett.

Koester—STEAM ELECTRIC POWER PLANTS. By Frank Koester. 21s. nett.

Lamb—ALTERNATING CURRENTS. By C. G. Lamb. 10s. 6d.

Lancaster—ELECTRIC COOKING, HEATING, CLEANING, &c. By Maud Lancaster. 3s. 6d. nett.

Larmor—ÆTHER AND MATTER. By Sir Joseph Larmor. 10s.

Leaf—THE INTERNAL WIRING OF BUILDINGS. By H. M. Leaf. Third Edition. 3s. 6d. nett.

Lehfeldt—ELECTRO-CHEMISTRY. By Prof. R. A. Lehfeldt. Part I.: General Theory. 5s.

Lummis-Paterson—THE MANAGEMENT OF DYNAMOS. By G. Lummis-Paterson. New Edition. 4s. 6d.

Lupton, Parr and Perkin—ELECTRICITY AS APPLIED TO MINING. By Arnold Lupton, G. D. A. Parr and H. Perkin. Second Edition. 12s. nett.

Lyndon—DEVELOPMENT AND ELECTRICAL DISTRIBUTION OF WATER POWER. By Lamar Lyndon. 17s. 6d. nett.

McAllister—ALTERNATING CURRENT MOTORS. By A. S. McAllister. Third Edition. 13s. nett.

Maclean—MODERN ELECTRIC PRACTICE. Edited by Prof. Magnus Maclean. Second Edition. Six vols. 54s.

Maclean—ELECTRICITY AND ITS PRACTICAL APPLICATIONS. By Prof. M. Maclean. 10s. 6d. nett.

McMeen and Miller—"TELEPHONY." By S. G. McMeen and Kempster B. Miller. 17s. nett.

McMillan—ELECTRO-METALLURGY, TREATISE ON. By Walter G. McMillan. Third Edition. Revised by W. R. Cooper, M.A., B.Sc. 12s. 6d. nett.

Malcolm—THE THEORY OF THE SUBMARINE CABLE. *See p.* 11.

Marchant—WIRELESS TELEGRAPHY. By W. H. Marchant. 5s. nett.

Marks and Clerk—ELECTRIC LIGHTING FOR MOTOR CARS. By Sir G. C. Marks and D. Clerk. 3s. 6d. nett.

Maycock—ELECTRIC LIGHTING AND POWER DISTRIBUTION. By W. Perren Maycock. In two vols. Vol. I., 7th Ed., 6s.; Vol. II., 7s. 6d.

Maycock—ELECTRIC WIRING, FITTINGS, SWITCHES AND LAMPS. By W. Perren Maycock. 6s. nett.

Meares—ELECTRICAL ENGINEERING IN INDIA. By J. W. Meares, M.Inst.C.E., M.I.E.E. 15s. nett.

Monckton—RADIO-TELEGRAPHY. By C. C. F. Monckton. [6s. nett.

Morecroft and Hehre—SHORT COURSE IN THE TESTING OF ELECTRICAL MACHINERY. By J. H. Morecroft and F. W. Hehre. 6s. nett

Morrow—STEAM TURBINE DESIGN: With Especial Reference to the Reaction Type. By Dr. John Morrow. 16s. nett.

Morse—STORAGE BATTERIES. By H. W. Morse. 6s. 6d. nett.

Munro—THE PRACTICE OF ELECTRIC WIRING. By D. S. Munro. 3s. nett.

Murdoch—VENTILATION OF ELECTRICAL MACHINERY. By W. H. F. Murdoch. 3s. nett.

Murdoch and Oschwald—ELECTRICAL INSTRUMENTS IN THEORY AND PRACTICE. By W. H. F. Murdoch and U. A. Oschwald. 10s. 6d. nett.

Metcalfe—PRACTICAL ELECTRIC WIRING FOR LIGHTING INSTALLATIONS. By Chas. E. Metcalfe. 5s. nett.

Neilson—THE STEAM TURBINE. By R. M. Neilson. 15s. nett.

Nerz—SEARCHLIGHTS; Their Theory, Construction and Application. By F. Nerz. Translated by Chas. Rodgers. 7s. 6d. nett.

Norris—INTRODUCTION TO THE STUDY OF ELECTRICAL ENGINEERING. By H. H. Norris. 10s. 6d. nett.

Northrup—METHODS OF MEASURING ELECTRICAL RESISTANCE. By E. F. Northrup. 17s. nett.

Ogley—INCANDESCENT ELECTRIC LAMPS AND THEIR APPLICATION By D. H. Ogley. 2s. 6d. nett.

Oudin — STANDARD POLYPHASE APPARATUS AND SYSTEMS. By Maurice E. Oudin, M.S, Fifth Edition 13s. 6d. nett.

Parham and Shedd—MISCELLANEOUS TESTS OF ELECTRIC CAR EQUIPMENT. By Eugene C. Parham and John C. Shedd. 4s. 6d. nett.

Parr—PRACTICAL ELECTRICAL TESTING IN PHYSICS AND ELECTRICAL ENGINEERING. By G. D. Aspinall Parr. 8s. 6d.

Parr — ELECTRICAL ENGINEERING IN THEORY AND PRACTICE. By G. D. Aspinall Parr. 12s. nett.

Patchell—APPLICATION OF ELECTRIC POWER TO MINES AND HEAVY INDUSTRIES. By W. H. Patchell. 10s. 6d. nett.

Peek—DIELECTRIC PHENOMENA IN HIGH VOLTAGE ENGINEERING. By F. W. Peek, jun. 12s. 6d. nett.

Pender—PRINCIPLES OF ELECTRICAL ENGINEERING. By H. Pender. 17s. 6d. nett.

Pendry—THE BAUDOT PRINTING TELEGRAPH SYSTEM. By H. W. Pendry. 2s. 6d. nett.

Perkin—PRACTICAL METHODS OF ELECTRO-CHEMISTRY. By F. Mollwo Perkin. 6s.

Perry—CALCULUS FOR ENGINEERS. By Prof. John Perry. 7s. 6d.

Pidduck—A TREATISE ON ELECTRICITY. By F. B. Pidduck. 14s. nett.

Pierce—PRINCIPLES OF WIRELESS TELEGRAPHY. By G. W. Pierce, M.A., Ph.D. 12s. 6d. nett.

Poole—THE PRACTICAL TELEPHONE HANDBOOK. By Joseph Poole. 6s. nett.

Poynting and Thomson—A TEXT-BOOK OF PHYSICS. By Prof. J. H. Poynting, D.Sc., F.R.S., and Prof. Sir J. J. Thomson, M.A., F.R.S. SOUND (Third Edition), 8s. 6d. PROPERTIES OF MATTER, Second Edition, 10s. 6d. HEAT 15s. MAGNETISM AND ELECTRICITY, 10s. 6d.

Preece and Sivewright—TELEGRAPHY. By Sir Wm. Preece, K.C.B., and Sir J. Sivewright, K.C.M.G. *New Edition.* By W. L. Preece. 7s. 6d. nett.

Pryde—MATHEMATICAL TABLES. By James Pryde. 4s. 6d.

Puppe — EXPERIMENTAL INVESTIGATIONS ON THE POWER REQUIRED TO DRIVE ROLLING MILLS. By J. Puppe. 12s. 6d. nett.

Raphael—LOCALISATION OF FAULTS IN ELECTRIC LIGHT MAINS. By F. C. Raphael. *See p.* 12.

Rhodes — ELEMENTARY TREATISE ON ALTERNATING CURRENTS. By W. G. Rhodes, M.Sc. 7s. 6d. nett

Richardson—MAGNETISM AND ELECTRICITY. By S. S. Richardson. 5s.

Richey and Greenhough—ELECTRIC RAILWAY HANDBOOK. By A. S. Richey, assisted by W. C. Greenhough. 17s. nett.

Rider—ELECTRIC TRACTION. By John H. Rider. 10s. 6d. nett.

Righi—MODERN THEORY OF PHYSICAL PHENOMENA, RADIO-ACTIVITY, IONS, ELECTRONS. By Prof. A. Righi. Translated by Prof. A. Trowbridge. 5s.

Rolfe-Martin—WIRELESS TELEGRAPHY. By A. B. Rolfe-Martin. 5s. nett.

Rosenberg—ELECTRICAL ENGINEERING. By E. Rosenberg. Translated by W. W. Haldane Gee and C. Kinzbrunner. 6s.

Rowe—ELECTRIC LIFTS AND HOISTS. By G. Rowe, M.I.E.E. *See p.* 12.

Ruhmer—WIRELESS TELEPHONY. By E. Ruhmer. Translated by Dr. J. Erskine Murray. 10s. 6d. nett.

Russell—ELECTRIC LIGHT CABLES AND THE DISTRIBUTION OF ELECTRICITY. By Stuart A. Russell. Second Edition. 10s. 6d.

Russell—A TREATISE ON THE THEORY OF ALTERNATING CURRENTS. By Alex. Russell, M.A. Vols. I. and II. 2nd Edition. 15s. nett each.

Russell—THE THEORY OF ELECTRIC CABLES AND NETWORKS. By Alex. Russell. 8s. nett.

Rutherford—RADIOACTIVE SUBSTANCES AND THEIR RADIATIONS. By Prof. Sir E. Rutherford. 15s. nett.

Rutherford—RADIOACTIVE TRANSFORMATIONS. By Prof. Sir E. Rutherford. 16s. nett.

Seabrook—THE MANAGEMENT OF PUBLIC ELECTRIC SUPPLY UNDERTAKINGS. By A. Hugh Seabrook. 7s. 6d. nett.

Schneider — CARE AND MANAGEMENT OF ELECTRIC POWER PLANTS. By Norman H. Schneider. New Edition. 5s. nett.

Schott—ELECTROMAGNETIC RADIATION AND MECHANICAL REACTIONS ARISING FROM IT. By G. A. Schott, D.Sc. 18s. nett

Seelig—WIRELESS TELEGRAPHY (Translation of Zennecke). By A. E. Seelig. 17s. nett.

Sewall—WIRELESS TELEGRAPHY: ITS ORIGIN, DEVELOPMENT. INVENTIONS AND APPARATUS. By C. H. Sewall. 10s. 6d. nett.

Slingo and Brooker—ELECTRICAL ENGINEERING: For Electric Light Artisans and Students. By Sir W. Slingo, A. Brooker and T. F. Wall. Revised and Enlarged Edition. 12s. 6d.

Slippy—TELEPHONE CABLES. By J. C. Slippy. 10s. 6d. nett.

Smith—HANDBOOK OF TESTING MATERIALS. By Prof. C. A. M. Smith. 6s. nett.

Smith—PRACTICAL ALTERNATING CURRENTS AND ALTERNATING CURRENT TESTING. By C. F. Smith. 5th edition. 6s nett.

Smith—ELECTRIC TRACTION. By Prof. R. H. Smith. 9s. nett.

Smith and Campbell—AUTOMATIC TELEPHONY. By Smith and Campbell. 17s. nett.

Snell—THE DISTRIBUTION OF ELECTRICAL ENERGY. By Sir John Snell. 18s. nett.

Snell—POWER HOUSE DESIGN. By Sir John Snell. 21s. nett.

Solomon—ELECTRICITY METERS. By H. G. Solomon. 16s. nett.

Solomon—ELECTRIC LAMPS. By Maurice Solomon. 6s nett.

·**Spooner**—MACHINE DESIGN, CONSTRUCTION & DRAWING. By H. J. Spooner. 10s. 6d. nett.

Stansfield—THE ELECTRIC FURNACE: ITS CONSTRUCTION, OPERATION AND USES. By Dr. A. Stansfield. 17s. nett.

Steinmetz—ELEMENTARY LECTURES ON ELECTRIC DISCHARGES, WAVES AND IMPULSES AND OTHER TRANSIENTS. By C. P. Steinmetz. 8s. 6d. nett.

Steinmetz—THEORETICAL ELEMENTS OF ELECTRICAL ENGINEERING. By C. P. Steinmetz. 3rd Edition. 17s. 6d.

Steinmetz—ENGINEERING MATHEMATICS. By C. P. Steinmetz. 12s. 6d. nett.

Steinmetz—RADIATION, LIGHT AND ILLUMINATION. By C. P. Steinmetz. 13s. 6d.

Steinmetz and Berg—THEORY AND CALCULATION OF ALTERNATING-CURRENT PHENOMENA. By C. P. Steinmetz & E. J. Berg. 17s. 6d.

Stevens and Hobart—STEAM TURBINE ENGINEERING. By T. Stevens and H. M. Hobart. 21s.

Still—POLYPHASE CURRENTS. By A. Still. 6s. nett.

Still—OVERHEAD ELECTRIC POWER TRANSMISSION: PRINCIPLES AND CALCULATIONS. By A. Still. 12s. 6d. nett.

Taylor—TRANSFORMER PRACTICE; MANUFACTURE, ASSEMBLING, CONNECTIONS, &c. 2nd Edition. By W. T. Taylor. 10s. 6d. nett.

Thomälen—A TEXT BOOK OF ELECTRICAL ENGINEERING. Translated from the German of Dr. A Thomälen. By Geo. W. O. Howe. 15s. nett.

Thompson—APPLIED ELECTRO-CHEMISTRY. By M. de K. Thompson. 9s. nett.

Thompson—DYNAMO-ELECTRIC MACHINERY. By Prof. S. P. Thompson Vol. I., C.-C. Machines; Vol. II., A.-C. Machinery. 30s. nett each Vol.

Thompson—LIGHT, VISIBLE AND INVISIBLE. By Prof. S. P. Thompson, D.Sc., F.R.S. 6s. nett.

Thompson—TREATISE ON LIGHT. By Chr. Huygens. Rendered into English by Prof. S. P. Thompson. 10s. nett.

Thomson—APPLICATIONS OF DYNAMICS TO PHYSICS AND CHEMISTRY. By Prof. Sir J. J. Thomson, F.R.S. 7s. 6d.

Thomson—THE CORPUSCULAR THEORY OF MATTER By Prof. Sir J. J. Thomson, F.R.S. 7s. 6d. nett.

Thomson—CONDUCTION OF ELECTRICITY THROUGH GASES. Second Edition. By Prof. Sir J. J. Thomson, F.R.S. 16s.

Thomson—ELEMENTS OF THE MATHEMATICAL THEORY OF ELECTRICITY AND MAGNETISM. By Prof. Sir J. J. Thomson. Fourth Ed. 10s.

Thomson—THE DISCHARGE OF ELECTRICITY THROUGH GASES. By Prof. Sir J. J. Thomson, F.R.S. 4s. 6d. nett.

Thomson—RAYS OF POSITIVE ELECTRICITY AND THEIR APPLICATION TO CHEMICAL ANALYSES. By Sir J. J. Thomson, F.R.S. 5s. nett.

Trotter—ILLUMINATION: Its Distribution and Measurement. By A. P. Trotter. 8s. 6d. nett.

Turner and Hobart—THE INSULATION OF ELECTRIC MACHINES. By H. W. Turner and H. M. Hobart. 10s. 6d.

Underhill—SOLENOIDS, ELECTROMAGNETS AND ELECTROMAGNETIC WINDINGS. By C. R. Underhill. 8s. nett.

Underhill—THE ELECTRO-MAGNET. By C. R. Underhill. 6s. 6d.

Von Schon—HYDRO-ELECTRIC PRACTICE. By H. A. E. C. Von Schon. 2nd Edition. 25s. nett. [5s. nett.

Wagstaff—A SCHOOL ELECTRICITY. By C. J. L. Wagstaff.

Walker—OUTLINES OF THE THEORY OF ELECTROMAGNETISM. By C. T. Walker. 3s. nett.

Walker—SPECIFICATION AND DESIGNS OF DYNAMO ELECTRIC MACHINERY. By Prof. Miles Walker. 32s. nett.

Walmsley—ELECTRICITY IN THE SERVICE OF MAN. By Prof. R. Mullineux Walmsley, D.Sc. Two vols. 7s. 6d. nett each.

Watson—PHYSICS, A TEXT BOOK OF. By Prof. W. Watson. 10s. 6d.

Watson—A TEXT BOOK OF PRACTICAL PHYSICS. By Prof. W. Watson. 9s. [6s. 6d. nett.

Watson—STORAGE BATTERIES. By A. E. Watson. 2nd Ed.

Whetham—RECENT DEVELOPMENTS OF PHYSICAL SCIENCE. By W. C. D Whetham, F.R.S. 7s. 6d. nett.

Whittaker—HISTORY OF THE THEORIES OF ETHER AND ELECTRICITY. By E. T. Whittaker. 12s. 6d. nett.

Wickenden—ILLUMINATION AND PHOTOMETRY. By Wm E. Wickenden. 8s. 6d. net. [7s. 6d. nett.

Wilkinson—CABLE LAYING AND REPAIRING. *See p.* 13.

Willows—A TEXT BOOK OF PHYSICS. By R. S. Willows.

Wilson and Lydall—ELECTRIC TRACTION. By Prof. E. Wilson and F. Lydall. Vol. I. Direct-Current; Vol. II. Alternating-Current. 15s. each.

Wilson—ELECTRIC TRACTION. By Prof. Ernest Wilson. 5s.

Wilson—EXPERIMENTAL PHYSICS. By H. A. Wilson, M.A., F.R.S. 10s. nett.

Woods—ÆTHER: A THEORY OF THE NATURE OF ÆTHER AND ITS PLACE IN THE UNIVERSE. By Hugh Woods, M.D., &c. *See p.* 13.

Wordingham—CENTRAL ELECTRICAL STATIONS. By Chas. H. Wordingham, A.K.C., M.Inst.C.E., M.I.M.E. Second Edition. 24s. nett.

Worrall—DRAWING FOR ELECTRICAL ENGINEERS. By G. W. Worrall. Edited by G. U. Yule. 2s. nett.

Wright—ELECTRIC FURNACES AND THEIR INDUSTRIAL APPLICATION. By J. Wright. 8s. 6d.

Zimmer—THE MECHANICAL HANDLING AND STORING OF MATERIAL. By G. F. Zimmer. 42s. nett.

SPECIAL NOTICE.

In addition to the supply of Technical and Scientific Books and Publications, "The Electrician" Company undertake the dispatch, on closest market terms, to any part of the world, of Works of Ficton, Travel, Biography, History, Theology, Reference Books, &c. Quotations given for Mixed Parcels of Books, from £3 upwards. Searches made for Rare and Scarce Books and Old Editions.

The Company has a department for the prompt dispatch of Daily, Weekly, and Monthly Periodicals to all parts of the world on best terms. Enquiries invited and Quotations submitted.

Printing and Stationery Supplies. Everything required for Station and Office Supplies. Typewriters (New and Secondhand) and Typewriter Supplies. Mimeograph, Cyclostyle and all other makes of Copying and Duplicating Apparatus. Photographic Outfits and Supplies, Gramophones and Gramophone Records on Best Terms.